Polarization

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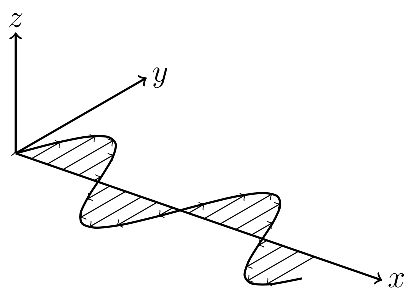
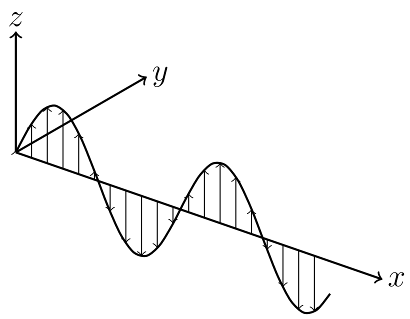
Polarization

A transverse wave's oscillations are perpendicular to the direction of motion. However, this could be one of an infinite number of such directions. If *all* the vibrations of a transverse wave are in a single plane which contains the direction of motion of the wave, the wave is said to be *plane-polarized* (or *linearly polarized*).

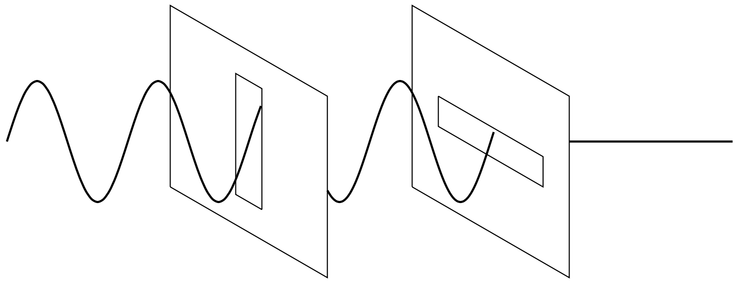
Polarization on a rope

Consider the two figures depicting transverse oscillations travelling along a rope below. Although the two waves are travelling in the same x-direction, the direction of oscillation of the rope is different in the two cases: on the left, the rope oscillates in the y-direction, and on the right, the rope oscillates in the z-direction.





We could say that the the wave on the left is plane polarized in the xy-plane, and the wave on the right is polarized in the xz-plane. We could design a 'filter' for polarization direction by using a thin slot, which will only let waves polarized in a certain direction through.

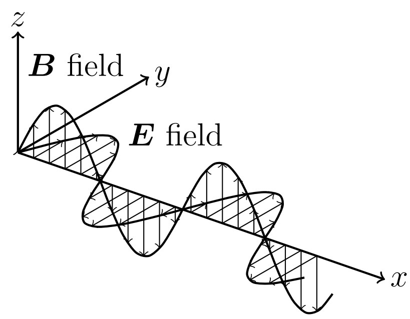


Although these waves can pass through the first slot, which is aligned with their polarization direction, they are totally unable to pass through the second.

Polarization gives us another important difference between longitudinal and transverse waves, as *only transverse waves can be polarized*[1].

Polarization of electromagnetic waves e.g. light

Electromagnetic waves are transverse, and it is the electric ($\boldsymbol{E}$) and magnetic ($\boldsymbol{B}$) fields which 'oscillate' perpendicular to the direction of motion:



Notice that the 'vibrations' of the electric and magnetic fields are perpendicular to each other, both are perpendicular to the direction of motion of the light wave, and they have the same frequency (in fact, at any moment, $\frac{E}{B} = c$, where c is the velocity of the light).

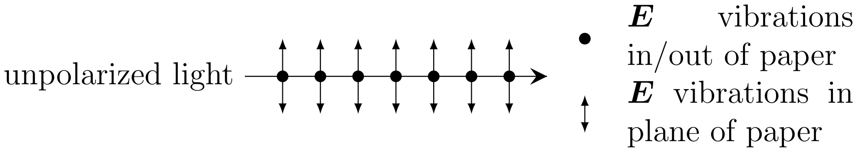
When light interacts with matter, it is the effects of the electric field oscillation that dominate (jiggle the electrons in atoms, develop photographic film and produce flourescence). Therefore, we take the direction of the $\boldsymbol{E}$-field oscillation to be the direction of polarization (in the case above, the light is plane polarized in the xy-plane.

Where do we find polarized light?

Most sources of light give out light whose polarization varies very rapidly with time (e.g. a filament bulb's polarization direction changes every 10^{-9} s) and light of this kind which (over

[1]In longitudinal waves, the oscillations can occur in only one direction: the direction the wave is moving

any reasonable time) will be a mixture of all possible polarization directions is said to be *unpolarized*:



Polaroid

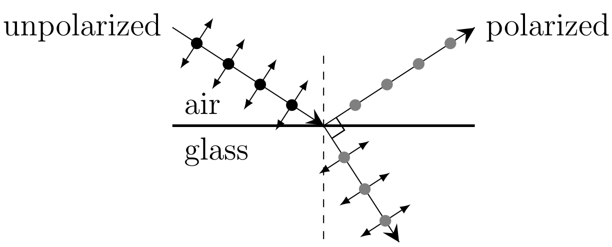
Polaroid is the trade name for a type of material[2] which only lets through light in one polarization direction. It acts just like the slot filters we considered for rope waves. This means that if unpolarized light is passed into a polaroid, only half of the light emerges on the other side (and half is absorbed), no matter what the orientation of the polaroid itself is.

Polaroids are used in liquid crystal displays (LCDs), like the ones found in flat computer monitors and calculators. The liquid crystal rotates the plane of polarization, allowing it to pass through a polaroid, but only if a small voltage is supplied by the graphics controller.

One useful application of this is in polaroid sunglasses, which contain polaroid in their lenses. These can reduce the glare from reflexions off surfaces such as water (since this reflected light is partly polarized), and are therefore particularly popular amongst fishermen.

Reflexions

If light hits a glass surface at an angle of incidence of about 57°—this is known as the Brewster angle for glass—the reflected light is completely plane polarized (this can be checked by viewing the light through a piece of polaroid or polaroid sunglasses and rotating the polaroid, which will block the light as it is rotated). At other angles of incidence, the reflected light will be partly plane polarized.



[2] If you really want to know, sheets of nitrocellulose in which are embedded crystals of quinine iodosulphate.