Ch. 4: Propagation of Light

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Propagation and scattering

Transmission, reflection, and refraction are all macroscopic manifestations of **scattering** occurring at the submicroscopic level.

Scattering is the absorption and prompt re-emission of radiation by electrons associated with atoms and molecules.

Think carefully about *phase*: the position of the imaginary “wheel” that makes a sinusoidal function. This “spins” as the photon (or wave) propagates thru space.

Rayleigh scattering—diffuse media

(figs. 4.1,4.2)

This is the elastic scattering that goes as ω^4, $1/\lambda^4$ discussed earlier. In a thin gas, the scattering from atoms is uncorrelated from the widely scattered atoms, and so energy leaves a beam of light in all directions.

The ω^4 dependence is responsible for blue-light scattering in upper atmosphere, and reddish sunsets.

Forward propagation

In a beam of light, all forward scattered wavelets have almost the same phase. They add (interfere) constructively in the forward direction.

In the lateral directions many slightly shifted phases will tend to add to zero (fig. 4.7). In dense media, the interatomic spacing d, where

$$d \ll \lambda,$$

there will always be scatterers of opposite phase, except in the forward direction. This *suppresses* lateral scattering.

Transmission—dense media In a solid medium, atoms are closer. There are $\sim 10^6$ atoms in a cube of side λ. There are always scattering centers to produce random phases in the lateral directions.

Little or no light ends up scattered laterally or backward in a dense homogeneous medium. (figs. 4.6–4.8)

Index of refraction

All this scattering advance retards the phases of the wavefront. In a dense medium the wavefronts progate at $v \neq c$. Usually $v < c$and $n > 1$, in unusual cases the phase retards so much it appears advanced and $v > c$ with $n < 1$, but this v is a *phase velocity* and carries no energy or information, it is due to interference.

See Table 4.1 for n for various materials.

Reflection For light traveling from medium of n_i (incident) into n_t (transmitted), $n_i < n_t$, there is an **external reflection**.

If $n_i > n_t$, there is **internal reflection**.

There is a π radians or 180° phase shift between internally and externally reflected light. When you bring two smooth pieces of glass together, this phase shift cancels the reflections.

A transparent medium reflects all colors about equally, due to scattering from many atoms.

(fig. 4.14)

Law of reflection

Two things to remember:

The angle of incidence equals the angle of reflection:

$$\theta_i = \theta_r$$

measured *from the perpendicular* (normal) to surface.

Rays are lines in direction of energy propagation, $\perp$ to wavefronts.

The incident ray, the perpendicular to surface, and the reflected ray all lie in the plane-of-incidence. (fig. 4.17)

Law of refraction—Snell's law

By arguing from the geometry of wavefronts at a surface (p. 101) and $n = c/v$:

$$n_i \sin\theta_i = n_t \sin\theta_t.$$

θ's are measured *from the perpendicular*.

The rays are **refracted** at the interface. Reflection occurs simultaneously.

Incident, reflected, and refracted rays all lie in the plane-of-incidence.

Animations from

`http://www.eftaylor.com/quantum.html`

These are designed to go with *QED* by Feynman.