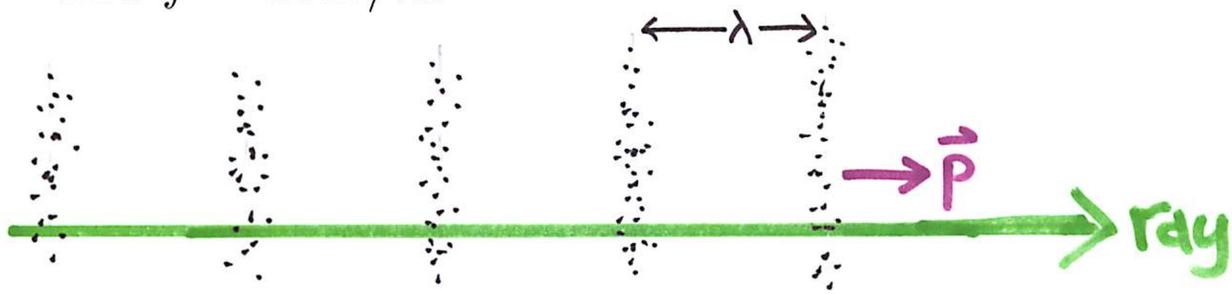
RAY OPTICS AND REFRACTION

All forms of light consist of photons, particles which are created when a charge is accelerated. If the charge is accelerated with frequency f the photons have $KE = hf$, where h is Planck's Constant, and momentum $p = KE/c$. The typical KE of a photon of visible light is several eV.

Light appeared to be waves when studied in the 18th through 19th Centuries because quantum particles like the photon, electron, etc., have probability distributions in space which are wavelike, with $\lambda = h/p$ and $f = KE/h$.



WAVES VERSUS RAYS:

In drawing sketches, it is far easier to draw ***rays***, which are lines perpendicular everywhere to the wave fronts, instead of a qualitative wave. After all, the actual waves of visible light have wavelengths of less than a millionth of a meter, which would not be possible to draw for processes on a human scale.

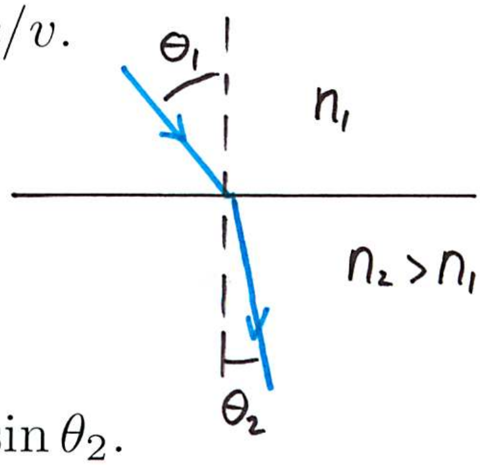
EARLY SCIENCE:

The science done circa 1000 to 1200 AD by Alhazen and Roger Bacon emphasized optics, and particularly refraction and reflection, because they could be studied in detail with simple tabletop experiments. Roger Bacon seems to have been the first person in history to do "lecture demonstrations."

DIFFUSE VERSUS SPECULAR REFLECTION:

To see an image and to quickly verify $\theta_1 = \theta_r$, you need a surface smooth compared to λ. Otherwise the reflected light "scatters," that is, is reflected in all directions. With a smooth surface, the incident beam is "reconstructed".

REFRACTION, SNELL'S LAW:



$$\text{Index of Refraction } n = c/v.$$

$$\lambda_1 n_1 = \lambda_2 n_2.$$

$$\text{Snell's Law}: n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

The index of refraction n is a function of λ or f, increasing with increasing f and decreasing with increasing λ. Thus red light has the smallest n and violet light the largest, for a given material.

HUYGENS' PRINCIPLE:

Wave propagation can be understood by assuming each point on a wavefront is a point source of new spherical waves. The new wavefront is just the superposition of all these "wavelets."

Total Internal Reflection:

When a wave travels from a material with n_1 to a material with n_2, and $n_2 < n_1$, there must be an angle $\theta_1 = \theta_c$ such that θ_2 is $90°$. For any angle $\theta_1 > \theta_c$, the wave is totally internally reflected, it cannot emerge into medium 2.

Fiber optics have become the basis of all intermediate-distance communication.

Metamaterials and n $<$ 0!

Since 1967 physicists have been exploring systems with a *negative index of refraction.* These materials usually consist of an array of identical elements that act as antennas or resonators when electromagnetic radiation passes through them. Such materials are currently the focus of extremely intense research. Various remarkable technological possibilities exist for these systems, including "superfocussing lenses" that produce sharp images of details *much smaller than the wavelength of the electromagnetic radiation used to form them,* something that sounds like a physical impossibility but is in fact easily achieveable.