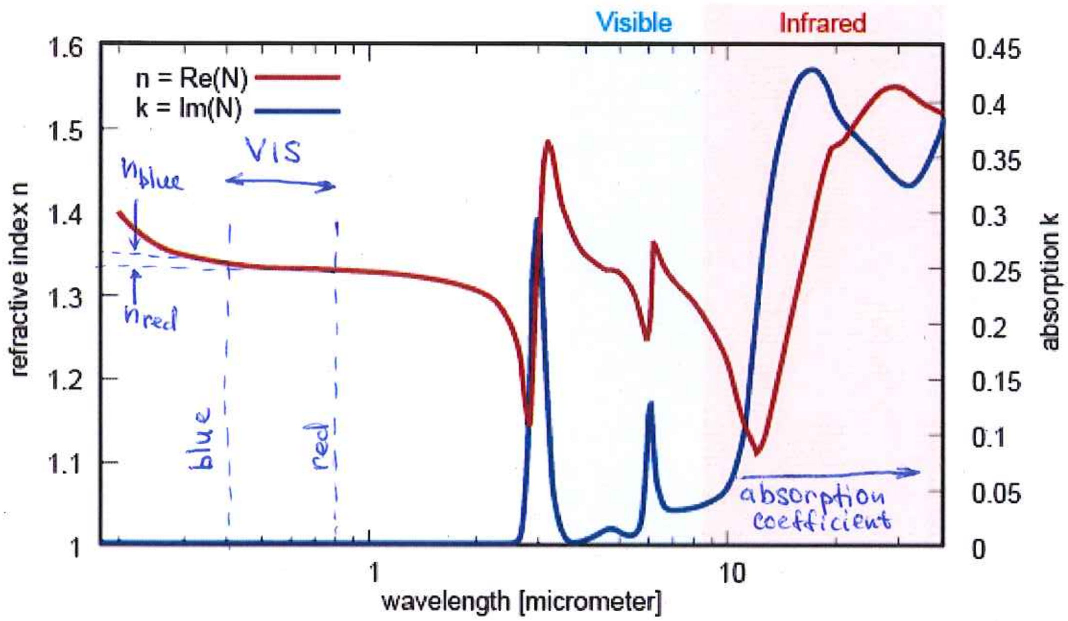
Laws of reflection and refraction

In vacuum light propagates with speed of light (usually labeled "c") and in streight line (with some approximations) → rey optics

In any material the speed on light is different (normally slower)
$v_{mat} = c/n$ n - refraction index

Why? Let's jump to e-m wave picture for a second.
Matter consists of atoms and molecules, that consist of nuclei and electron. An e-m wave affect these electrons, and can make them oscillate.
Usually, the electrons inside atoms are not free to move at any frequency, so the response to an incoming e-m wave is the strongest when its frequency is closest to a resonanse - internal responce frequency of an electron.
Usually at these frequencies the incoming e-m wave is strongly absorbed.
However, even far away from such resonance frequencies the light will make electrons shake a little bit, (without much absorption), and these oscillating electrons start emitting their own e-m field at the same frequency, but likely with some delay. Total field we detect is the combination of the original and re-emitted field, and thus it propagates slower.

Dispersion curve of water



<u>Blue curve</u> shows what portion of the light is absorbed by the material. Notice – no absorption in visible range, but strong resonances around 1.2 μm, 1.6 μm, and above 10 μm

<u>Red curve</u> shows refraractive index. The strongest variation in the refractive index is right around the resonance frequency, but then the value of the refractive index changes at frequencies far enough from the resonance, when the absorption practically vanishes.

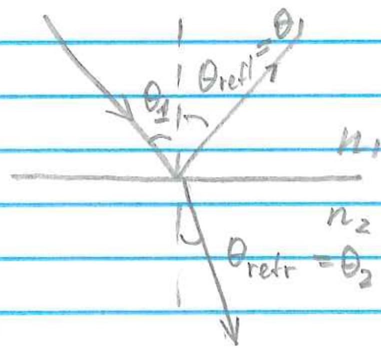
For example, across the visible spectrum the absorption coefficient of water is almost zero, but there is still small change in the refractive index b/w red light (0.8 μm wavelength) and blue light (0.4 μm wavelength).

And we should thank this change for rainbows!

Also, the closer the light frequency to the resonance frequency, the larger is the change in the refractive index. Most ~~transparent~~ materials we use (glass, water, christals) have resonances in UV (frequencies higher than visible), thus blue light has higher refractive index than red ($f_{blue} > f_{red}$)

There are certain rules about how the amplitudes of the electric and magnetic field must change on the boundary of two materials ⟹ Maxwell eqns!

However, two processes take place
reflection → part of the initial beam returns to the same material
refraction → part of the beam continues into the new material, often shifting its direction



$\theta_{refl} = \theta_1$

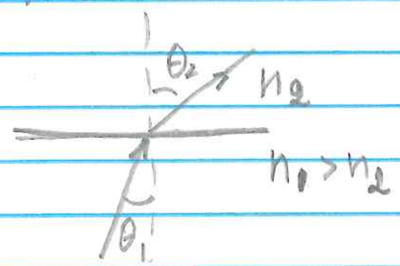
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
Snell's law

Each polished flat surface will reflect the beam (all or partially). If the surface is rough, different microspots will reflect differently → diffuse reflection or scattering.

How to reflect all light?

1. Use polished metal → mirror
(free electrons inside the metal prevent e-m field from entering inside, screening it) so small fraction of energy is absorbed, but the rest is reflected.

2. Use total internal reflection



$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 > n_2 \Rightarrow \theta_1 < \theta_2$

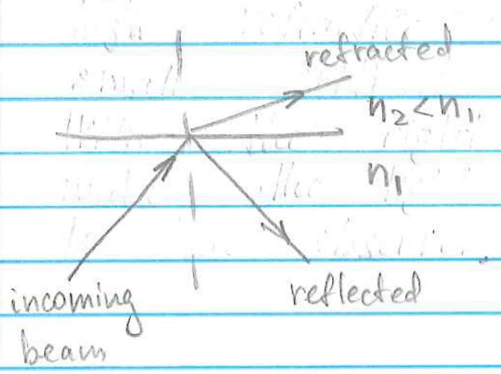
$\max \theta_2 = 90° \rightarrow \theta_1 = \theta_{critical}$

$n_1 \sin\theta_{cr} = n_2$

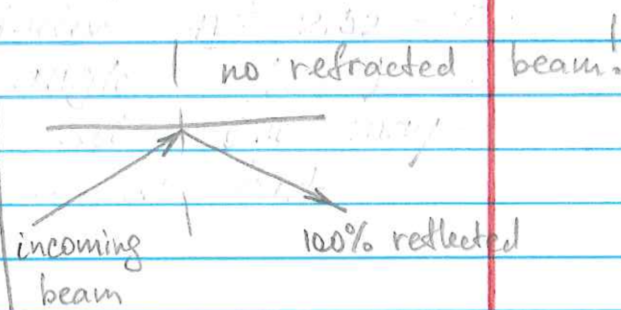
$$\boxed{\sin\theta_{cr} = \frac{n_2}{n_1}}$$

For any $\theta_1 > \theta_{cr}$ all the light will be reflected, none will propagate beyond the boundary

$\theta_1 < \theta_{cr}$



$\theta_1 > \theta_{cr}$



Things looks funny when in water