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…gives a brief introduction to the science of lasers, and the mathematics that are involved.

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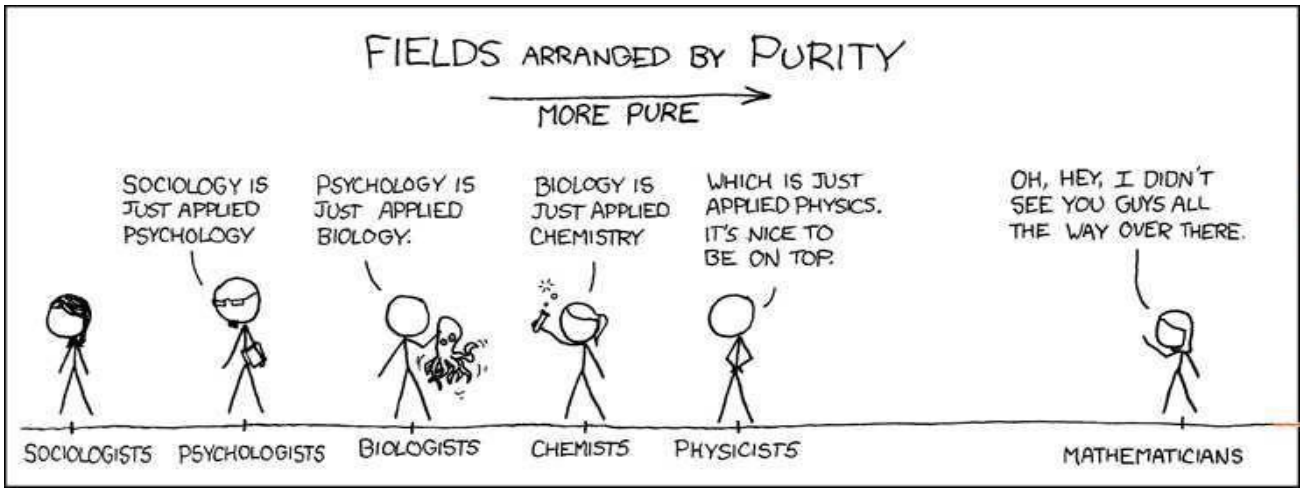
Why study mathematics?

"You know we all became mathematicians for the same reason: we were lazy." -- Max Rosenlicht



"Applied mathematics is mathematics for which I happen to know an application. This, I think, includes almost everything in mathematics." -- Henry O. Pollack

But what *is* mathematics?

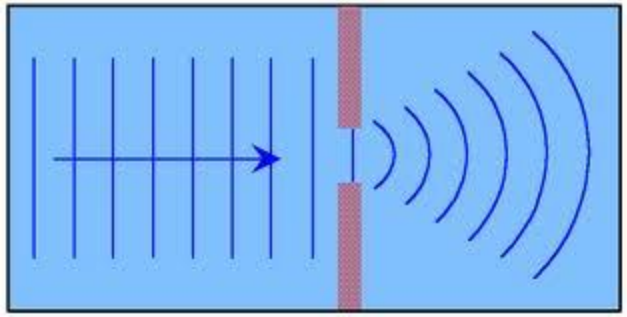
1. The abstract science of number, quantity, and space;
2. The art of problem solving.

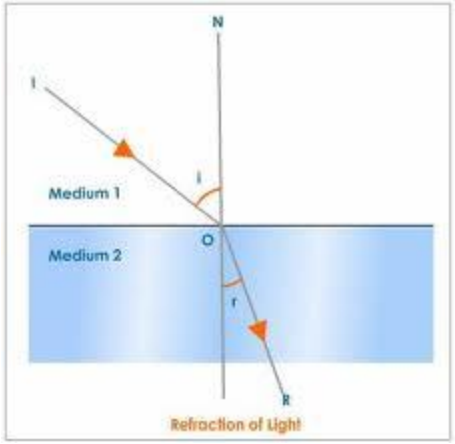
Light: Diffraction, Refraction, & Lenses

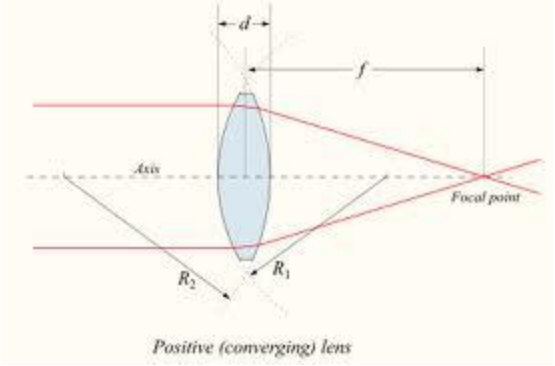
1. Diffraction:
Light wants to spread out so that it fills all of space. This is a *defocusing* effect.

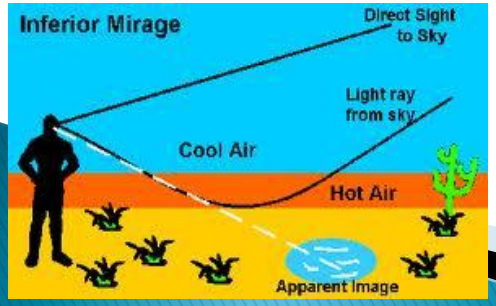
2. Refraction:
Light rays bend when passing from one material into another. The amount of bending is determined by the *refractive index.*

3. Lenses:
A device that can be used to control refraction and *focus* the light rays.







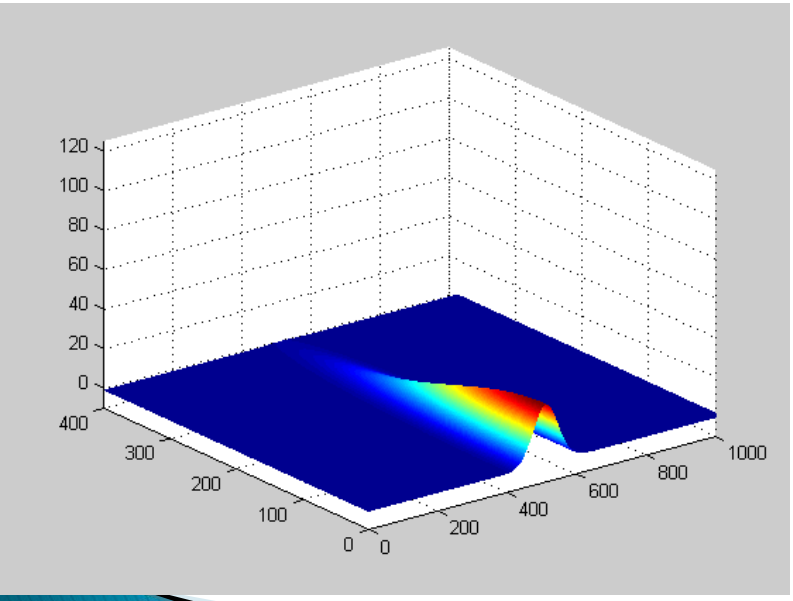


Real life example: the "highway mirage" is created when air near the surface of the road is heated, creating a different refractive index.

The self-focusing phenomenon

Key observation: changing the temperature of a material (such as air) can change its refractive index. Thus, hotter air can create a lens!

The physics: First, a laser is fired into the air. Next, because the center of the beam is more intense (hotter), the refractive index here is higher. This then causes the light near the outside of the beam to bend towards the center, making the beam even more intense and narrower. This cycle can continue all the way until the air is destroyed (by ionization, for example).



The mathematics:
The simplest parts of this phenomenon can be described by a well-known equation:

$$i\frac{\partial A}{\partial Z}+\Delta A+|A|^2 A=0$$

However, to understand the effects created by the ionization process, we must use *perturbation theory,* which enables us to analyze a more complicated equation:

$$i\frac{\partial A}{\partial Z}+\Delta A+|A|^2 A+\varepsilon(other\ terms)=0$$

What can the math tell us?

So far, we can make predictions about:

- Where the beam self-focuses;
- The shape of the beam as it collapses;
- The input power required to begin the self-focusing process.

We would like to know:

- When/how does the process stop?
- How will two of these self-focusing beams interact with each other?
- How does the experimental setup (e.g. polarization) affect the focusing dynamics?

But who really cares?

The deep-pocketed DoD, of course. Potential applications include:

- Directed lightning strikes;
- Laser beam death rays;
- Popping popcorn from outer space.