Washtenaw County Elementary Science Olympiad

Photon Phun Workshop 3

Refraction

Prof. Katsuyo Thornton

Prof. Max Shtein

Dept. of Materials Science and Engineering

Univ. of Michigan

Presented at Scarlett Middle School

Financial support by National Science Foundation

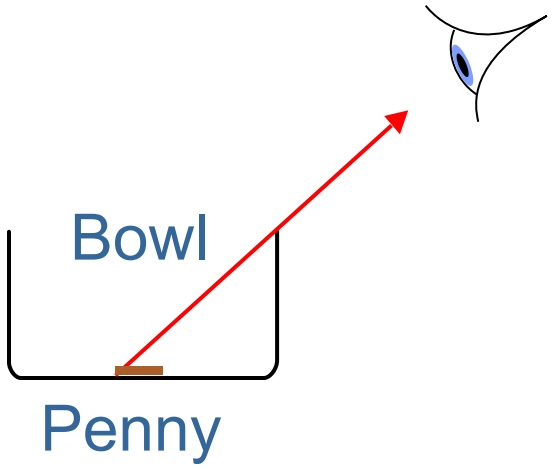
What will we learn today…?

- Refraction
  - Bowl & penny
  - Water tank
- Application of Refraction
  - Water droplet on hydrophobic surface
- How do we see things
- How materials influence light?
  - Microwave
- Measuring index of refraction

See materials section at the end for the supplies for activities

Activity 1: Penny in a bowl

- Tape a penny at the bottom of a bowl
- Position your eye so you can just see the penny over the rim of the glass
- Now, the coach will fill the bowl
- What happened to the penny?
- How can you explain?



What did you see?

What did you see?

- The penny appears!

Refraction

- Light changes direction when encountering another transparent material with different index of refraction

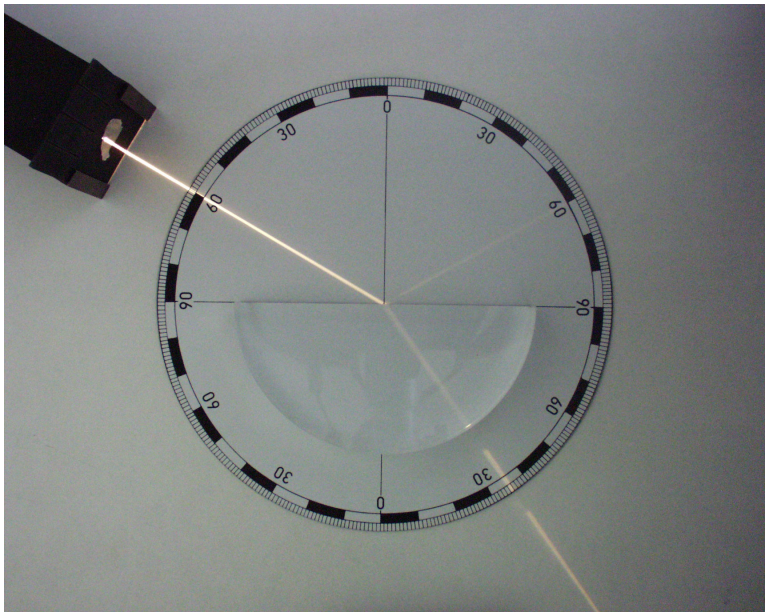


Image: https://en.wikipedia.org/wiki/Refraction

Refraction

- Light changes direction when encountering another transparent material with different index of refraction

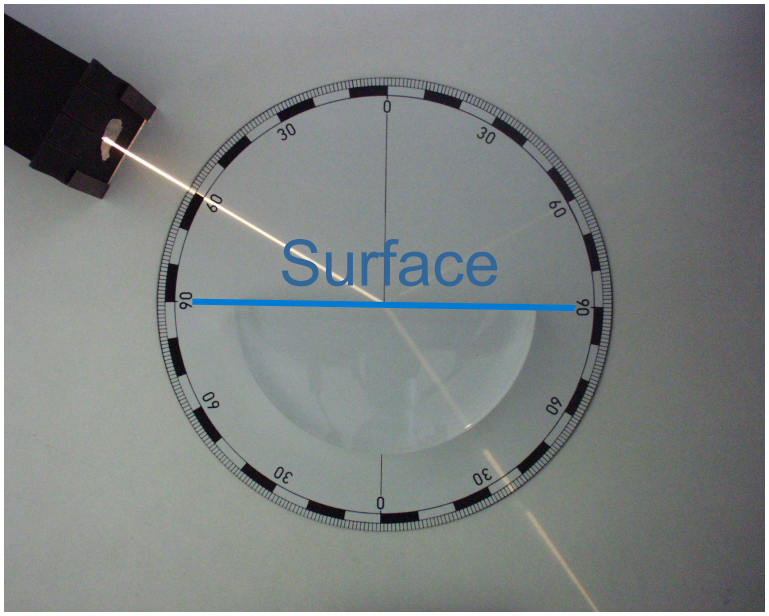


Image: https://en.wikipedia.org/wiki/Refraction

Refraction

- Light changes direction when encountering another transparent material with different index of refraction

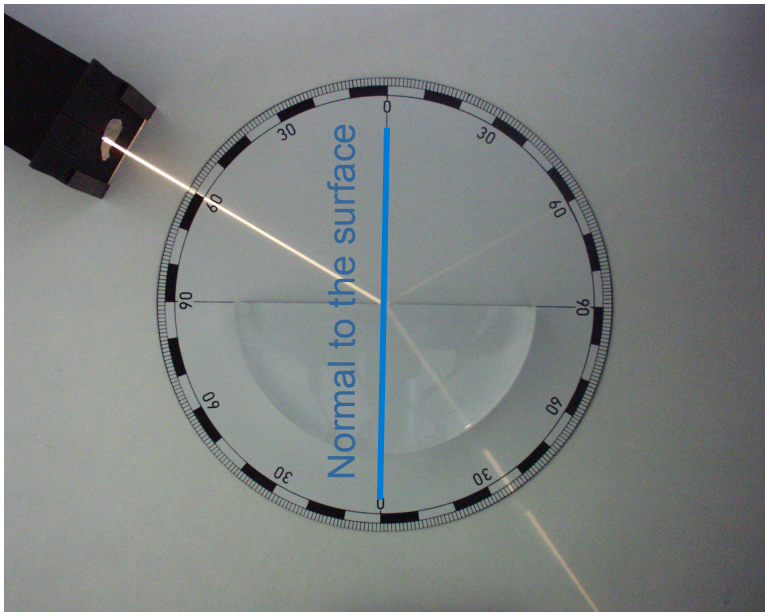


Image: https://en.wikipedia.org/wiki/Refraction

Refraction

- Light changes direction when encountering another transparent material with different index of refraction

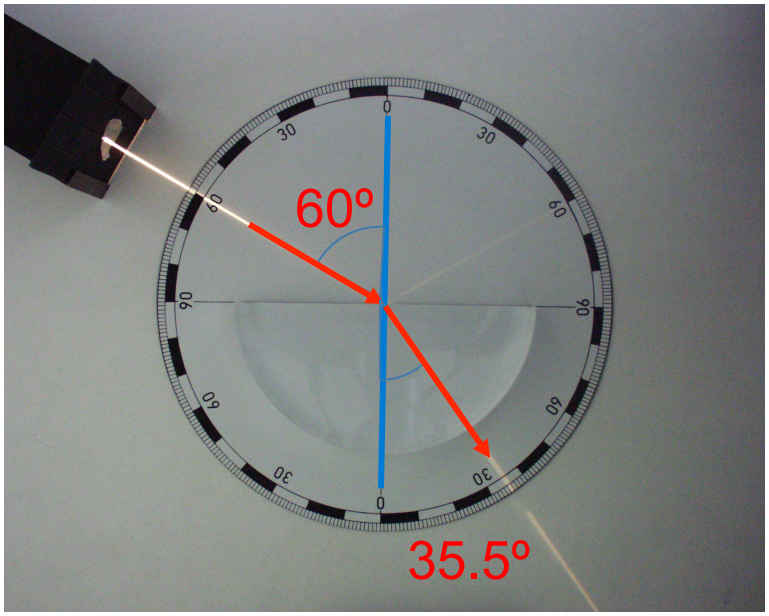
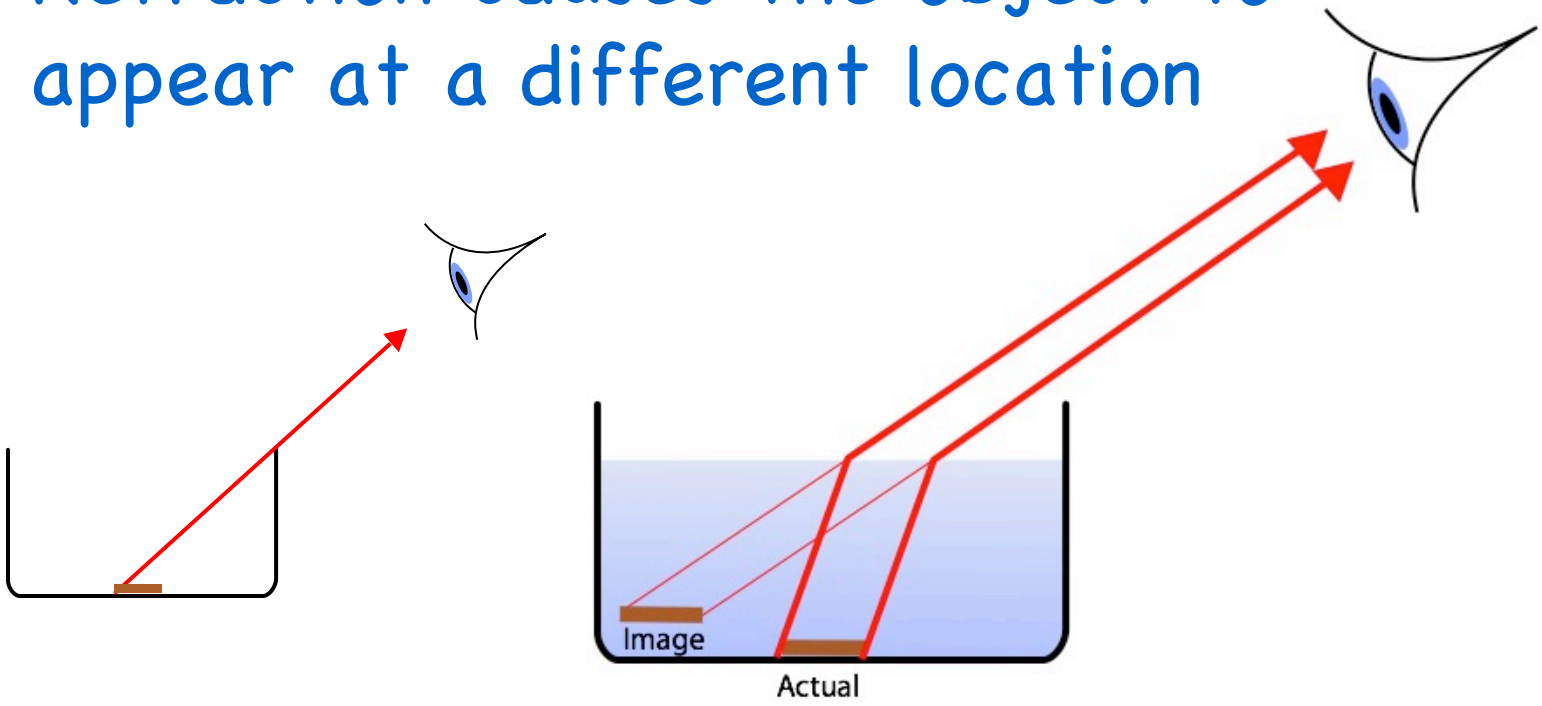


Image: https://en.wikipedia.org/wiki/Refraction

So, what happened to the penny?

- Refraction causes the object to appear at a different location



Where else do you see refraction?

Where else do you see refraction?

- In pool
- Fish tanks
- A glass of water
- Eye glasses

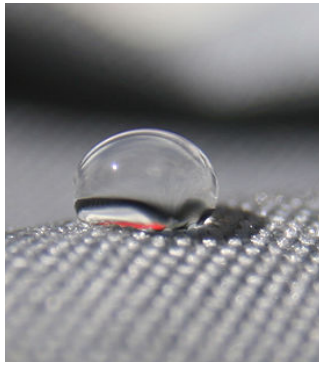
When is refraction useful?

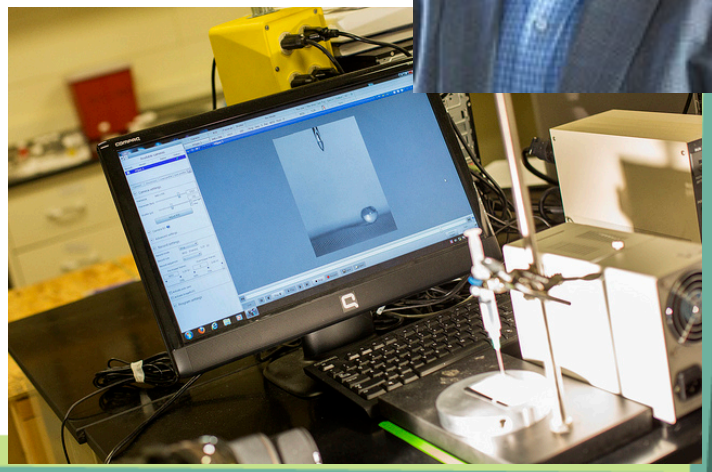
When is refraction useful?

- Lenses are in
  - Cameras
  - Eye glasses
  - Telescopes
  - Contact lenses
  - Magnifiers

Activity 2: Background

- Hydrophobic surfaces repels water
- Surfaces that repel liquids are good for keeping surfaces clean
- Researchers like Prof. Anish Tutaja at UM is developing new materials that repel both oil and water





Images: (top left) https://en.wikipedia.org/wiki/Contact_angle
(others) courtesy of Prof. Anish Tutaja, UM

Activity 2: What's the joke?

- Take one sheet of clear vinyl
- Put a very small drop of water
- Use it to magnify the little letters on the paper
- Share the joke with your table

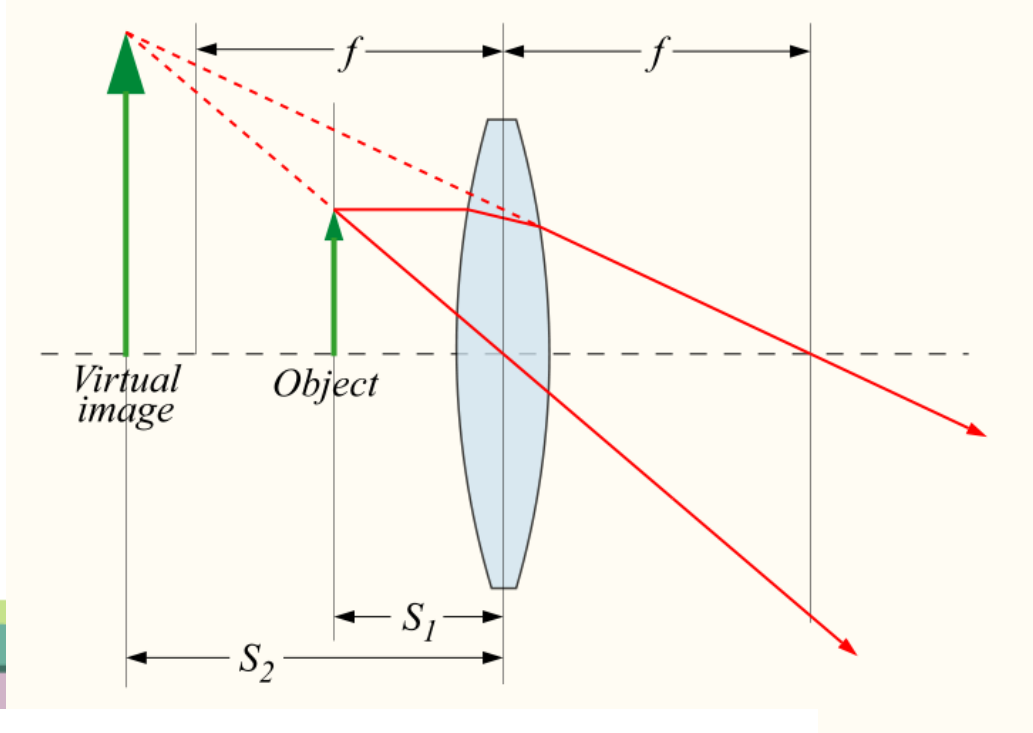
How does it work?

How does it work?

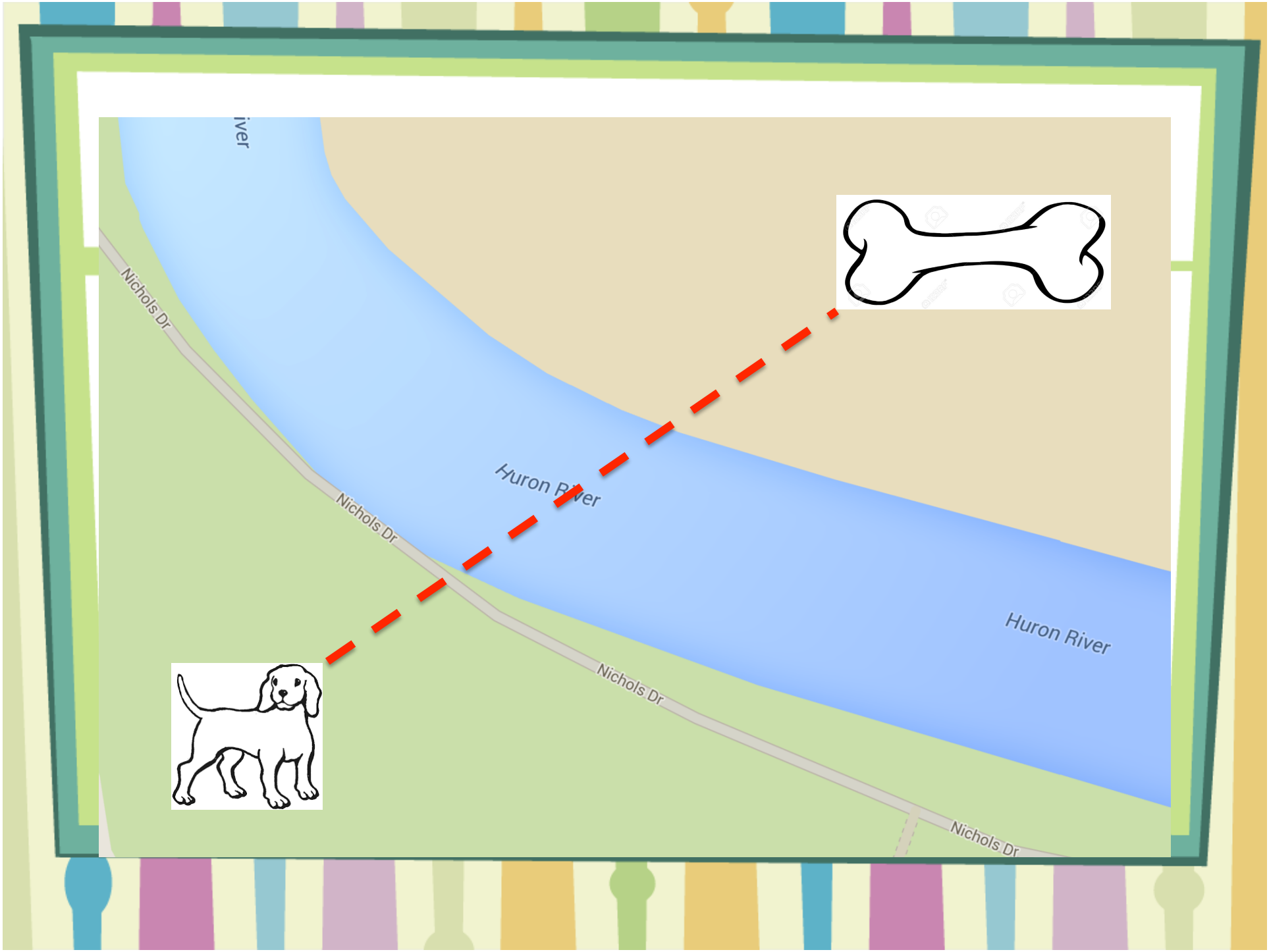
- The water droplet works like a lens!

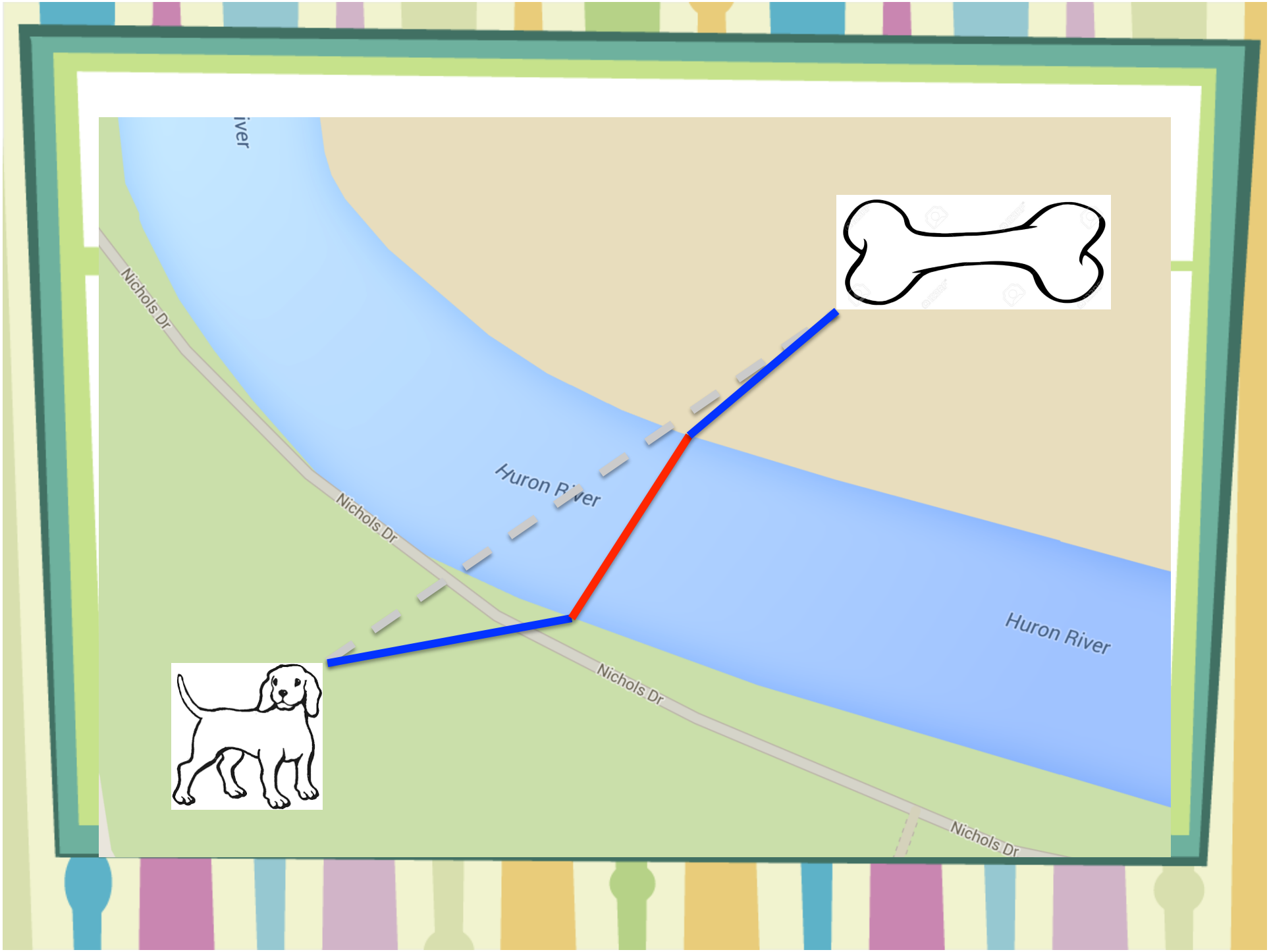
A lens moves the object image via refraction

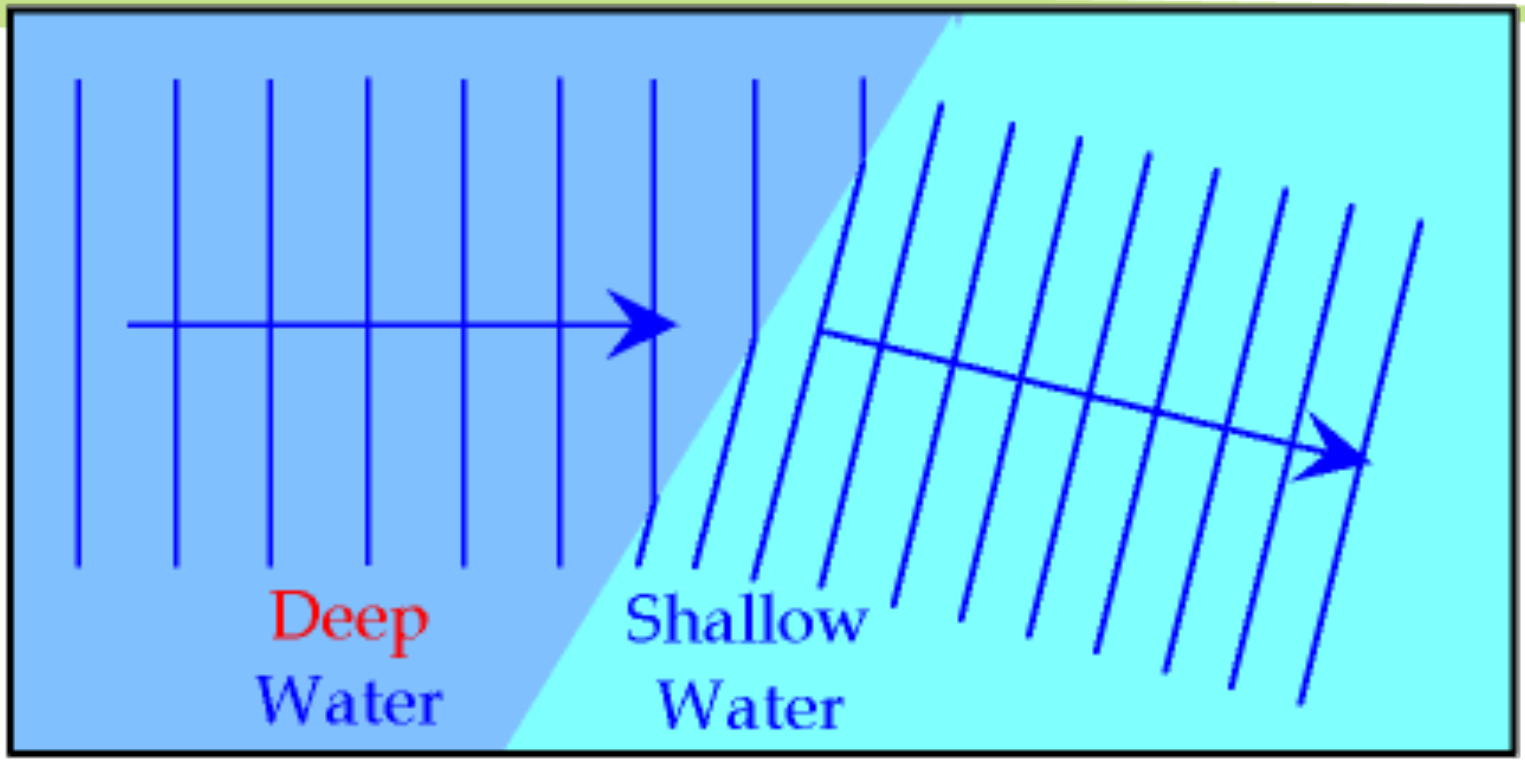
- A lens moves the object image in a way it is not uniform but rather stretches it

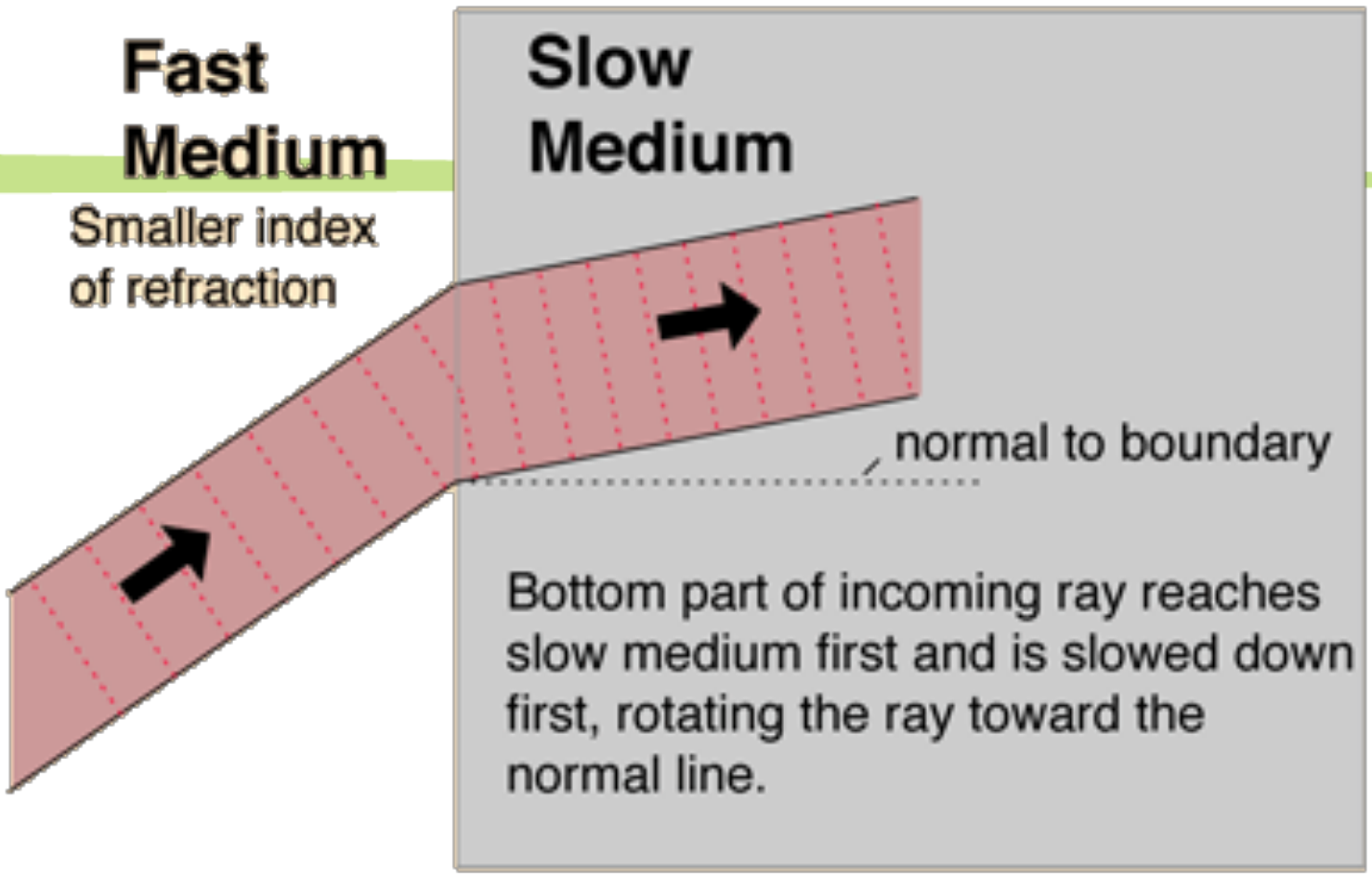


https://en.wikipedia.org/wiki/Lens_(optics)


iver
Nichols Dr
Huron River
Nichols Dr
Huron River
Nichols Dr
Nichols Dr


Nichols Dr
Huron River
Nichols Dr
Huron River
Nichols Dr
Nichols Dr

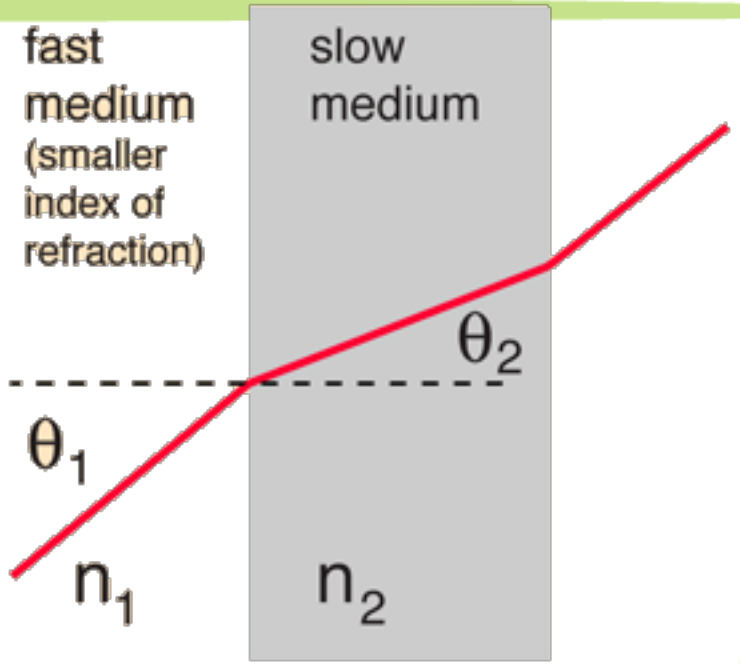

Deep
Water
Shallow
Water



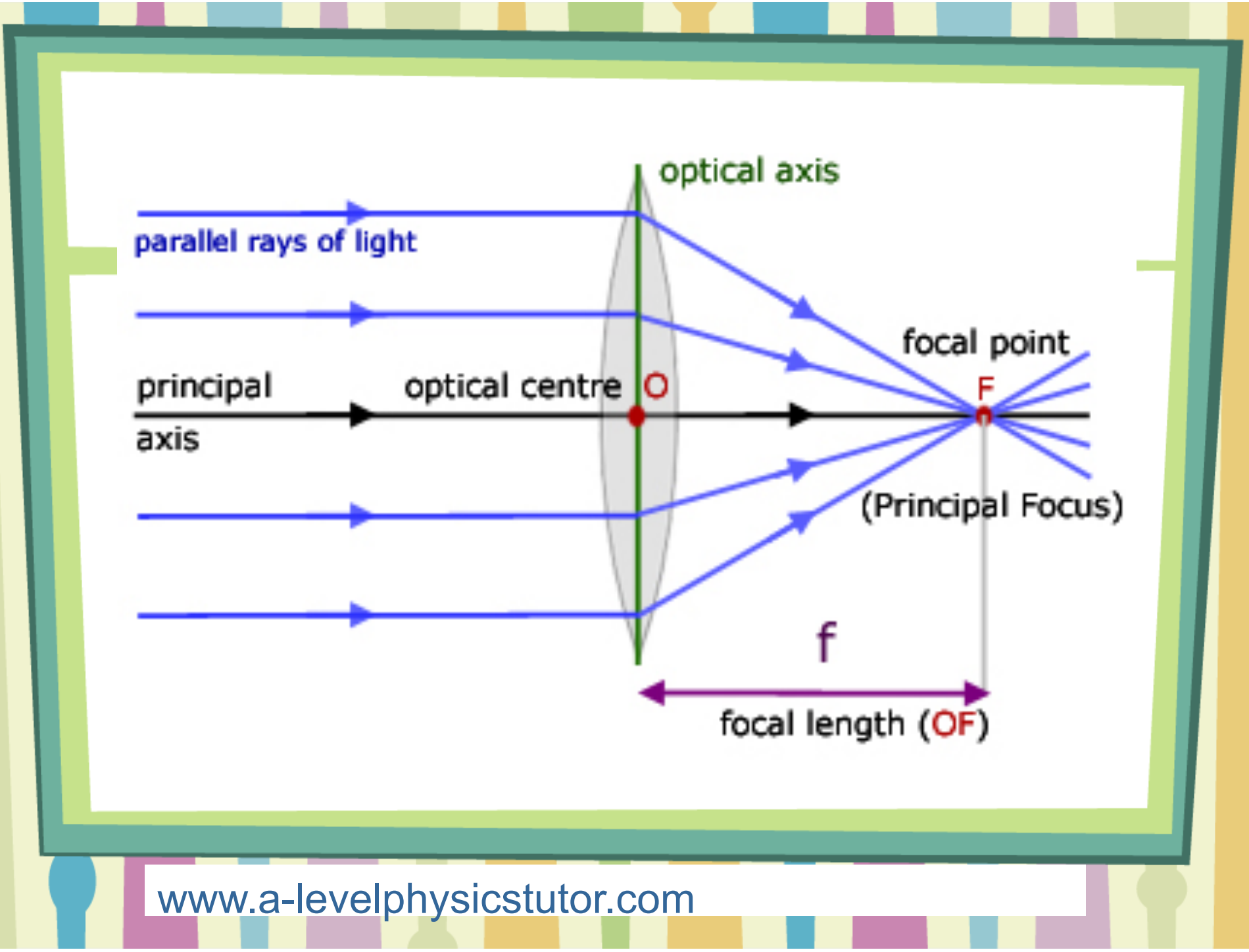
http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/refr.html

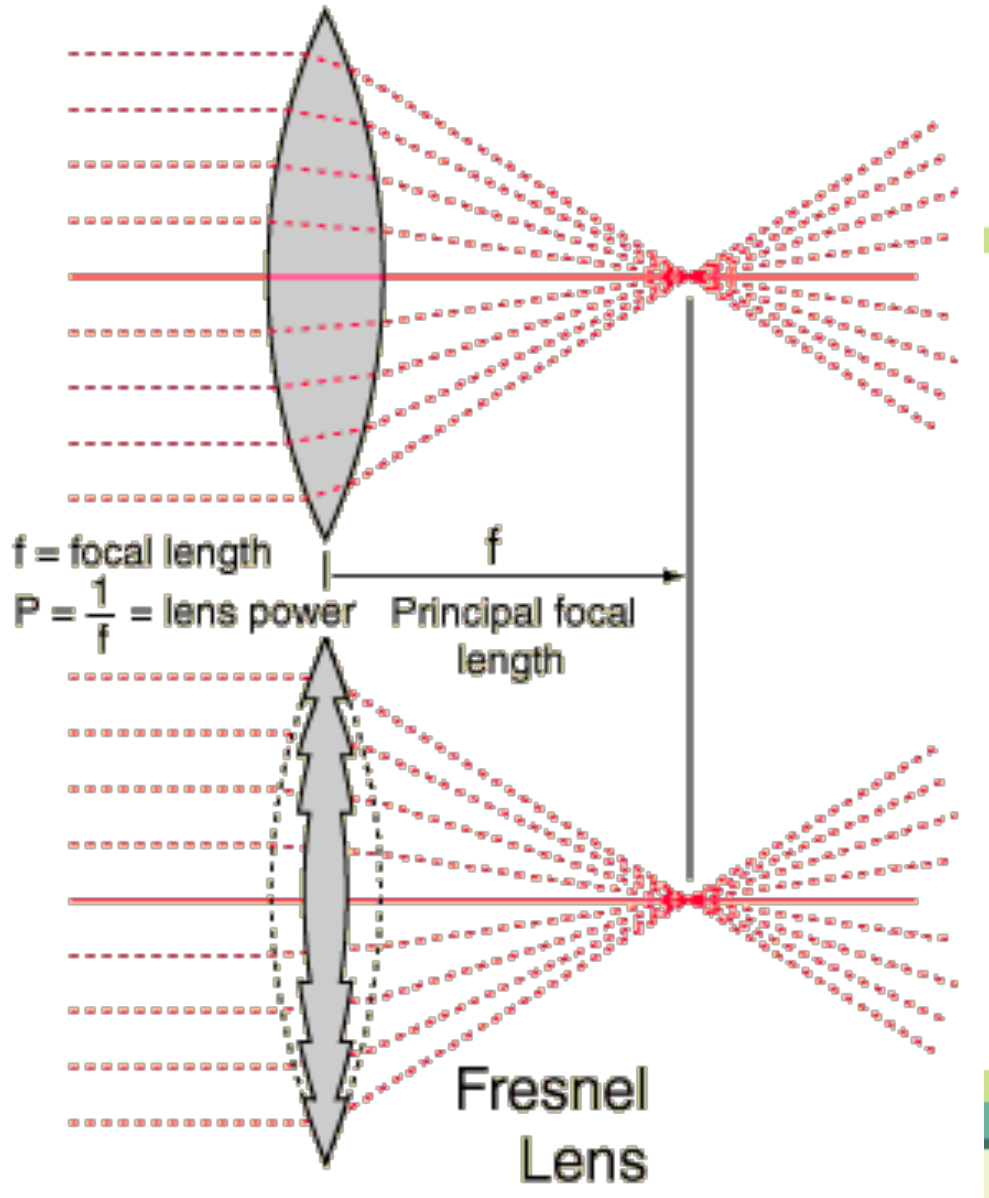
Snell's Law

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

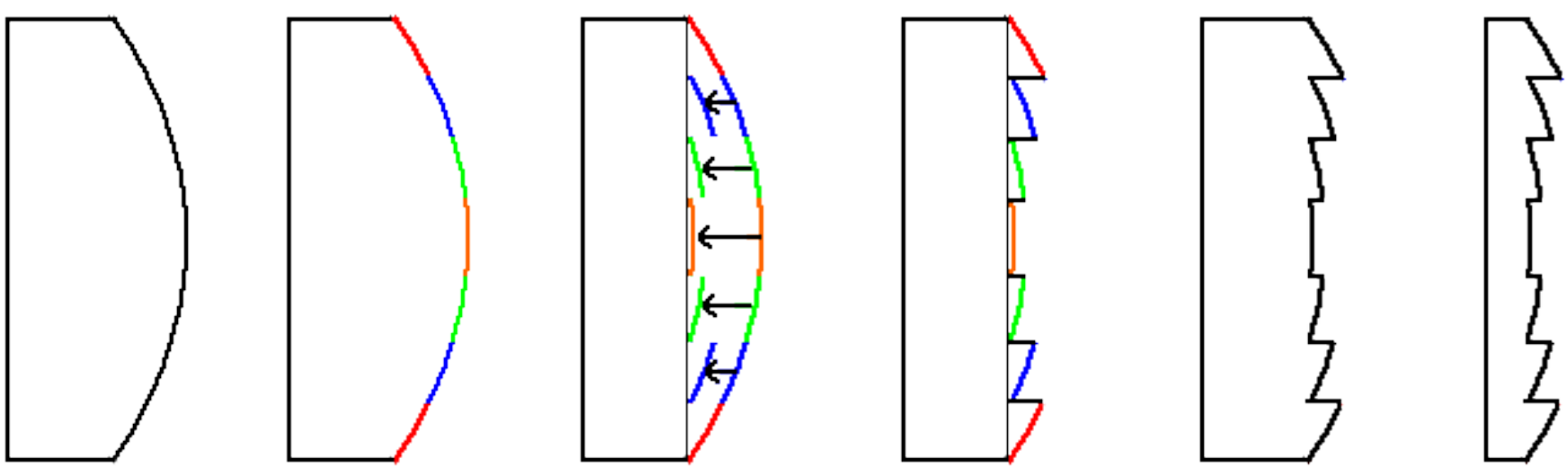


http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/refr.html





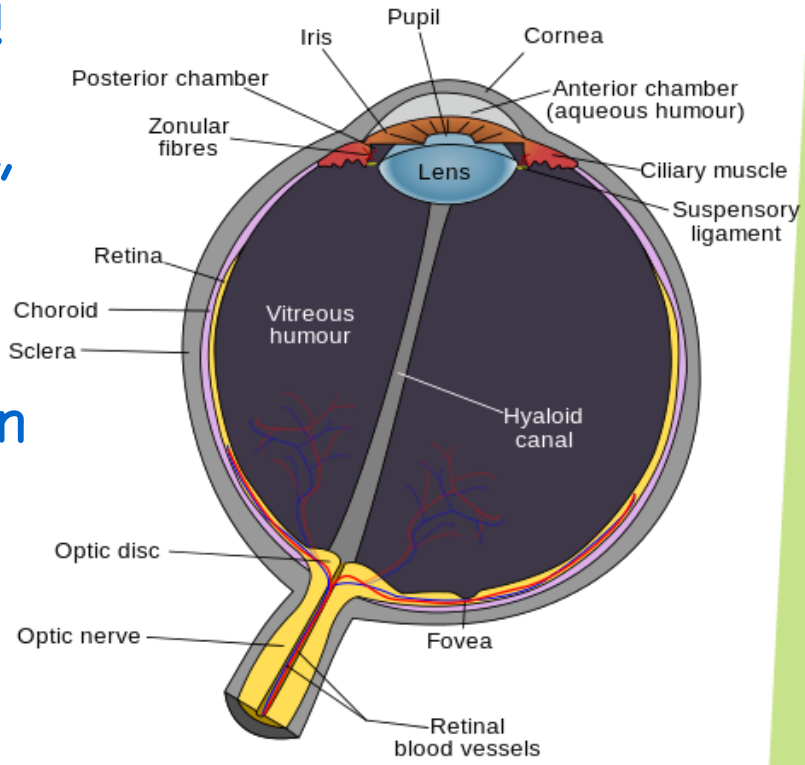
http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/fresnellens.html



http://physics.stackexchange.com/questions/68609/optics-for-projecting-oled-screen-dlp-style

How do we see things?

- Our eyes have lenses, too!
- The image is focused by the lens onto the "screen" at the back of the eye, which has "sensors" that are connected to the brain through optic nerve



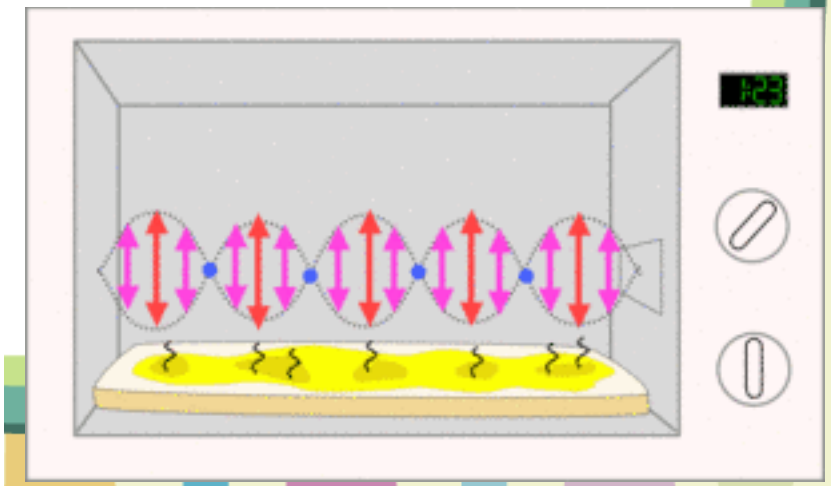
https://en.wikipedia.org/wiki/Eye

How does material influence light?

- Review: light can be absorbed, reflected, or can refract upon encounter with another material
- Review: light is electromagnetic wave
- Atoms contain charged particles (electrons, protons)
- Electromagnetic wave interacts with these charges; depending on the interaction, it can result in absorption, reflection, and refraction

Microwave

- **Microwave** ovens use waves at a specifically set frequency to move water molecules in food
- Standing EM wave is generated
- Molecular vibration and friction cause heat
- Uneven heating



http://www.thenakedscientists.com/HTML/experiments/exp/measuring-the-speed-of-light/

Activity 3: Microwave

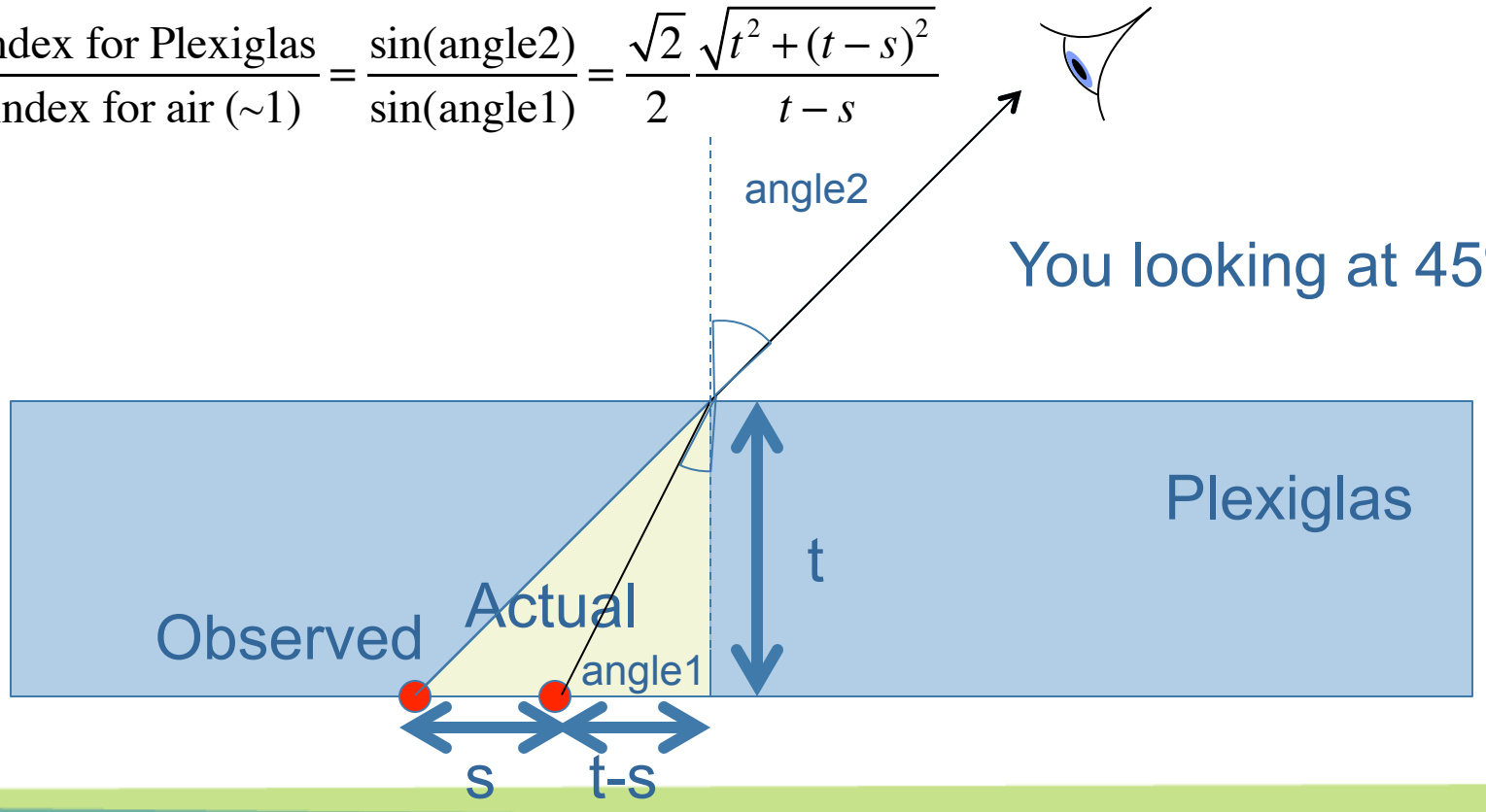
- Find the wavelength of the microwave by finding the hot spots!
- Spread marshmallows and microwave it until just when you see a few hot spots (melting)
- Measure the distance between them.

Activity 4 (challenging): Measuring the Index of Refraction

- Put a block of Plexiglas on a gridded paper (1mm grid with a reference red line)
- Look at the line at 45 degree angle
  - Fold a paper to make a 45 degree to use as a guide
- How many millimeters does the red line shift?
- Bring the number to me to obtain the measured index

Where does the formula come from? Snell's Law

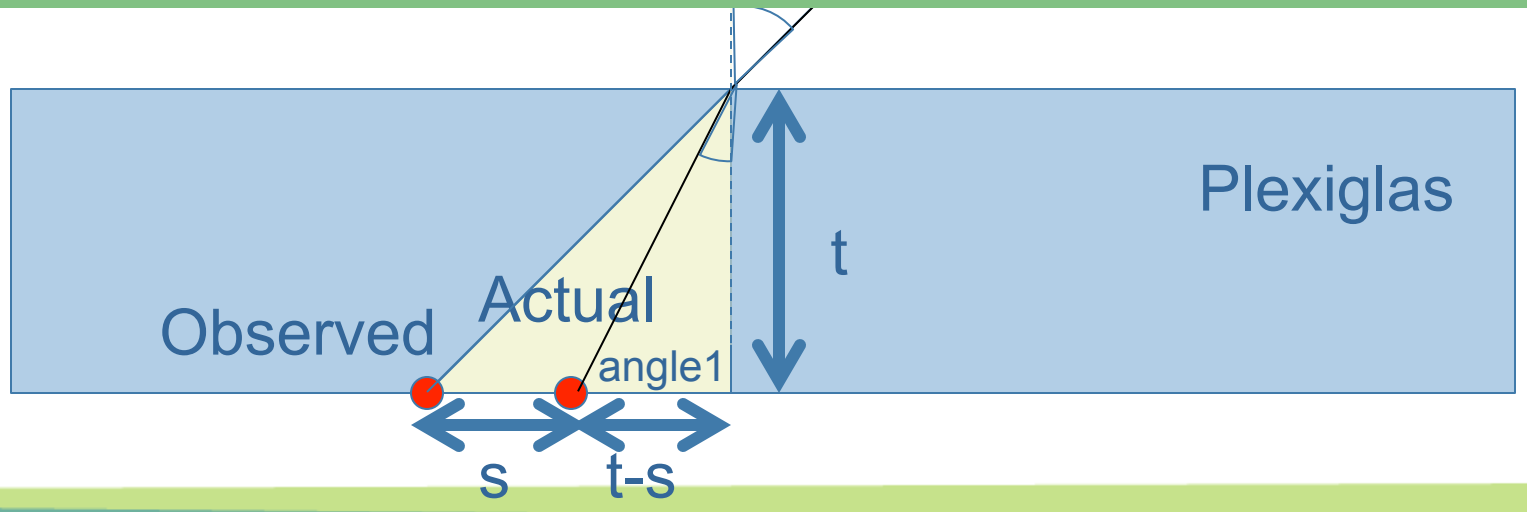
$$\frac{\text{index for Plexiglas}}{\text{index for air } (\sim 1)} = \frac{\sin(\text{angle2})}{\sin(\text{angle1})} = \frac{\sqrt{2}}{2}\frac{\sqrt{t^2+(t-s)^2}}{t-s}$$



Where does the formula come from? Snell's Law

$$\frac{\text{index for Plexiglas}}{\text{index for air } (\sim 1)} = \frac{\sin(\text{angle2})}{\sin(\text{angle1})} = \frac{\sqrt{2}}{2}\frac{\sqrt{t^2+(t-s)^2}}{t-s}$$

Math is important! Study hard!



Take-away…

- Light refracts when it goes through a different transparent materials (i.e., different index of refraction)
- It can be useful (lenses, magnifier)
- Light interacts with materials because it's electromagnetic wave and materials have charged particles
- Microwave is a electromagnetic wave that interacts with water molecule

Thanks!

Questions?

Supplementary Materials for Coaches and Parents

Activity Materials

- Activity 1: A bowl, a penny, and tape
- Activity 2: Heavyweight vinyl envelopes, dropper (optional), jokes printed with 3pt font on a good printer
- Activity 3: Mini marshmallows, plates, and microwave
- Activity 4: A thick plastic piece, graph paper with 1mm grid, one line marked in red