

Lenses and Polarization

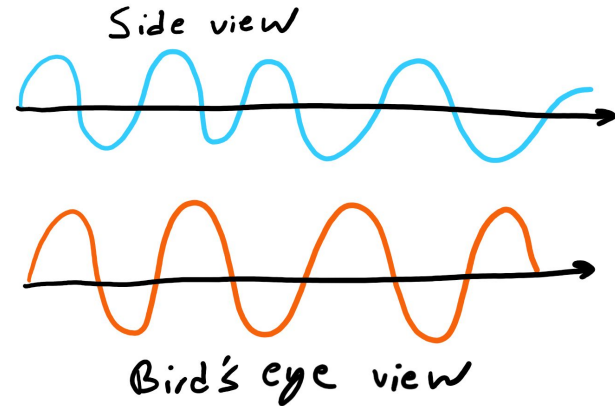
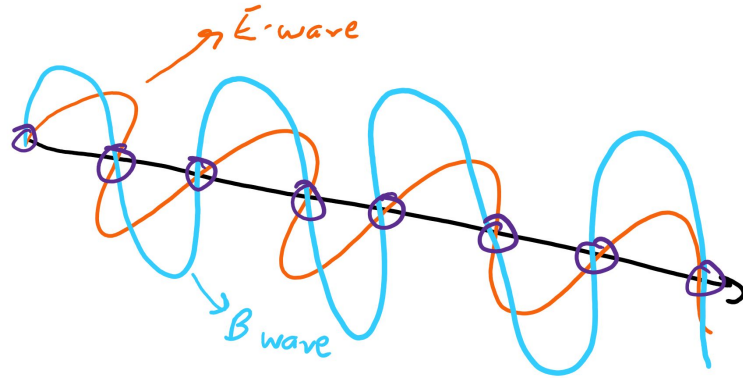
Colours? Only 36 Slides

Polarization

What does light look like?

Electromagnetic wave:

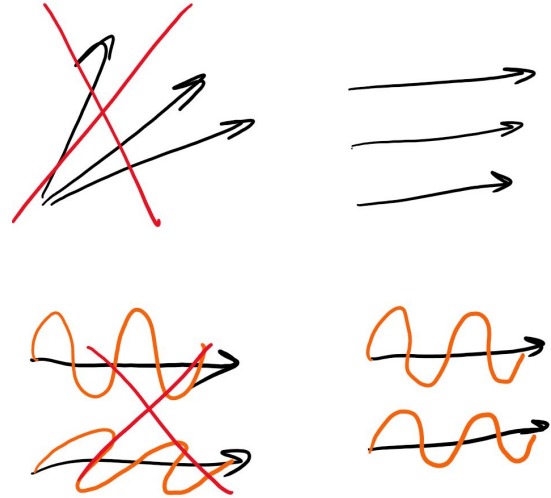
- Combination of, well, electric and magnetic waves
- They're perpendicular to each other
- Constantly destroying and creating itself
- In purple are the places the “wave destroys itself”



Polarization?

What is Polarization?

- “Polarized light waves are light waves in which the vibrations occur in a single plane”
- All the light travels in the same direction
- All the electric fields are oriented the same way



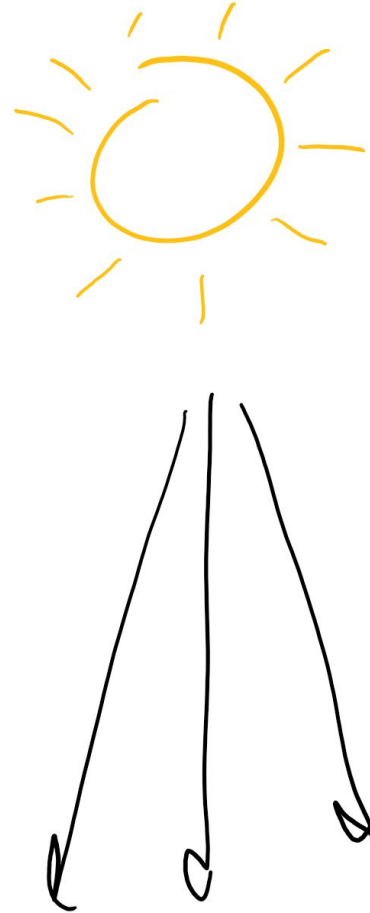
Polarization 2 electric boogaloo

What does it mean?

- What is light normally like?
- What if it's polarized?

What are some examples of non-polarized light?

- Sun
- Most light sources



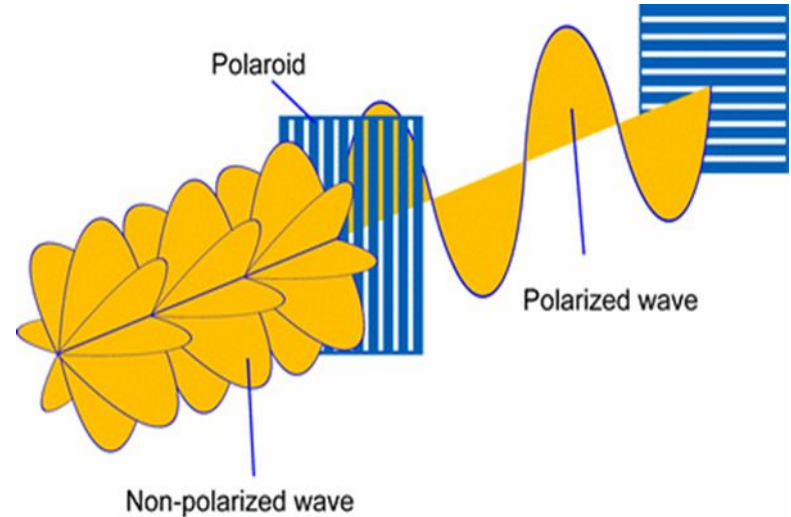
Where does Polarized light come from? Part 1

Polaroids:

- Diffraction gratings
- Block light in a specific orientation

Reflection

- Non-Metallic Reflections Polarize Light
 - Snow
 - Roads
 - Water



Types of polarization

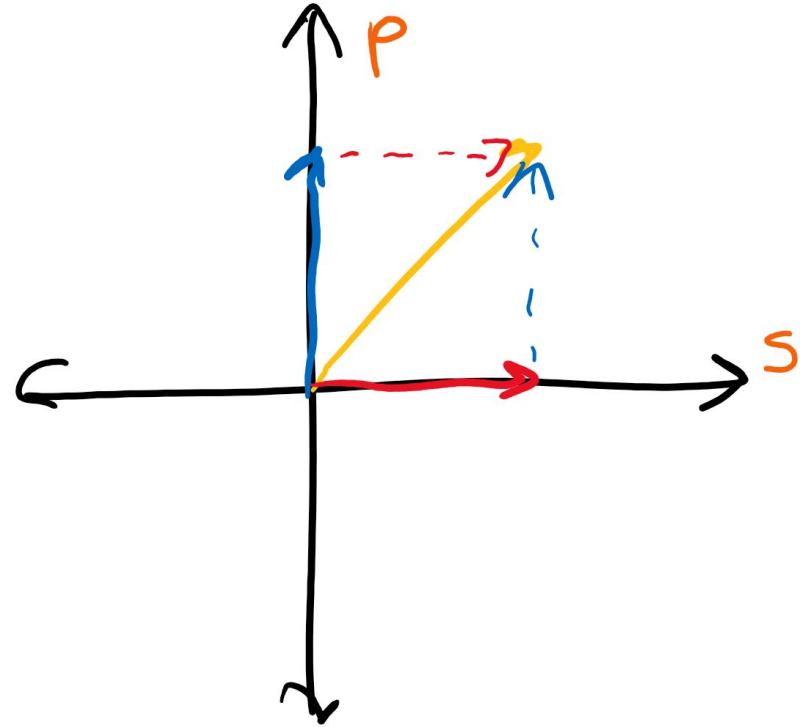
S-polarized

- Polarization parallel to the “surface”

P-polarized

- Polarization perpendicular to the “surface”

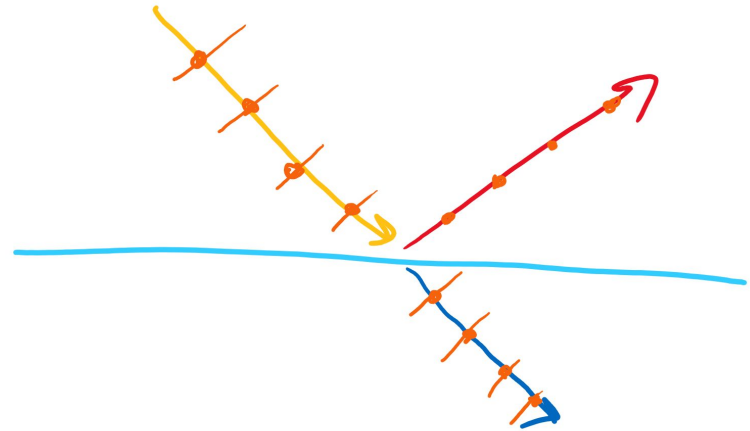
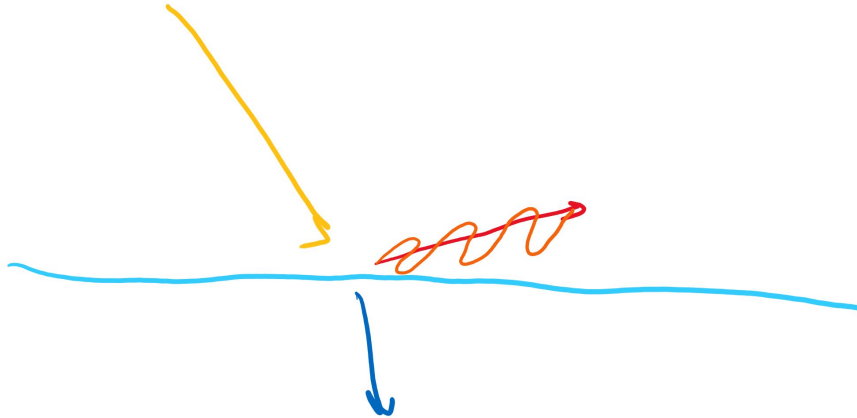
P and S are perpendicular to each other



Where does Polarized light come from? Part 2

Refraction/Reflection:

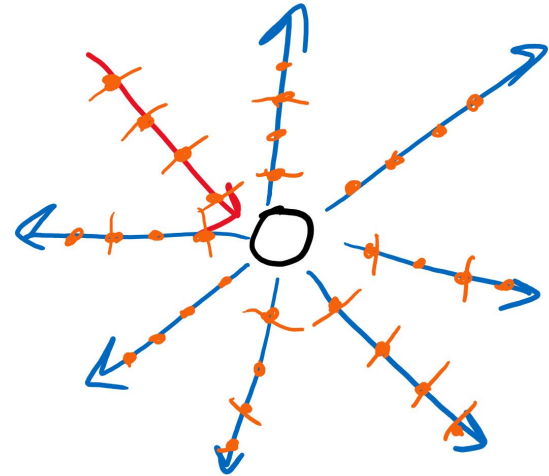
- Brewster's angle extended
- Refracted ray is Perpendicular to reflected ray
- Causes perfect Polarization



Where does Polarized light come from? Part 3

Scattering:

- Only Partially Polarized
- Particles will re emit light in certain orientations
- Causes glare when looking at sky
- Cameras and polaroid filters



Uses?

Some uses of polarization are:

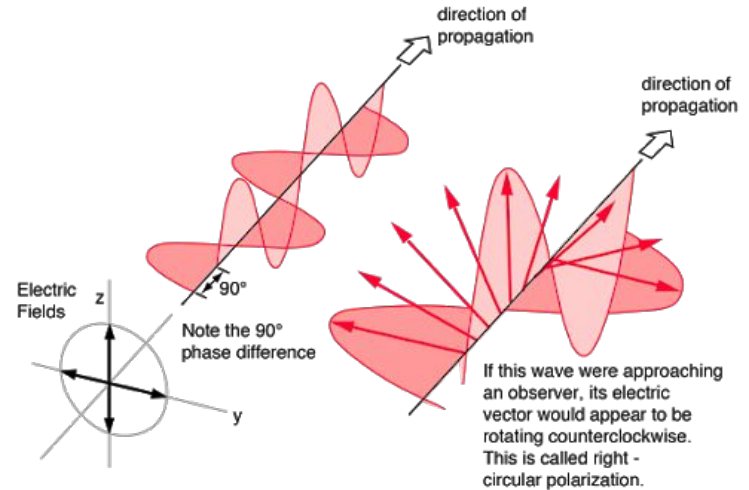
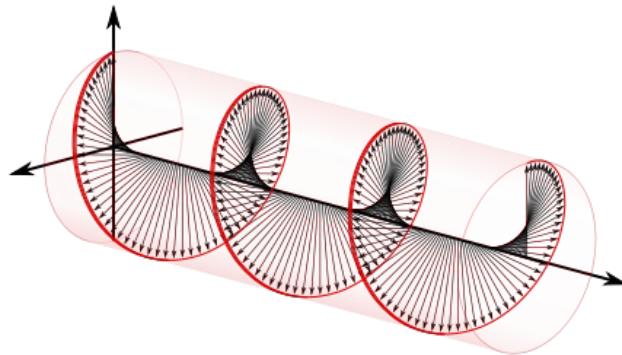
- Decreasing intensity by a controllable amount:
 - Sunglasses
 - What happens if 2 filters block light perpendicularly?
- Reduction of Glare
 - Glare is caused by polarized light, so Polaroid filters lessen glare
- Helps see where transparent materials are most fragile
 - Filters on a protractor will see bands which are weaker
- 3D movies?

Circular polarization?

Interference can cause the polarization to spin in a circle, either clockwise or counterclockwise

3D glasses can also use circular polarization

- Left eye sees clockwise
- Right sees counterclockwise
- Or vice-versa



Interesting effects

Take light and pass it through a polaroid

Set another polaroid at a 45 degree angle to it

Set a third at a 45 angle to the previous one

The first and the third are 90 degrees off, so no light should pass right?

Wrong! The 45 degree polaroid made it so the light can actually pass through!

Another barrier increased the light that passed through!

Review

What is polarization?

Where does non-polarized light come from?

Where does polarized light come from?

What are some of its uses?

What happens if we have 2 filters at a 90 degree angle to each other and pass light through both of them? What if we add a filter between at 45 degrees?

Colors

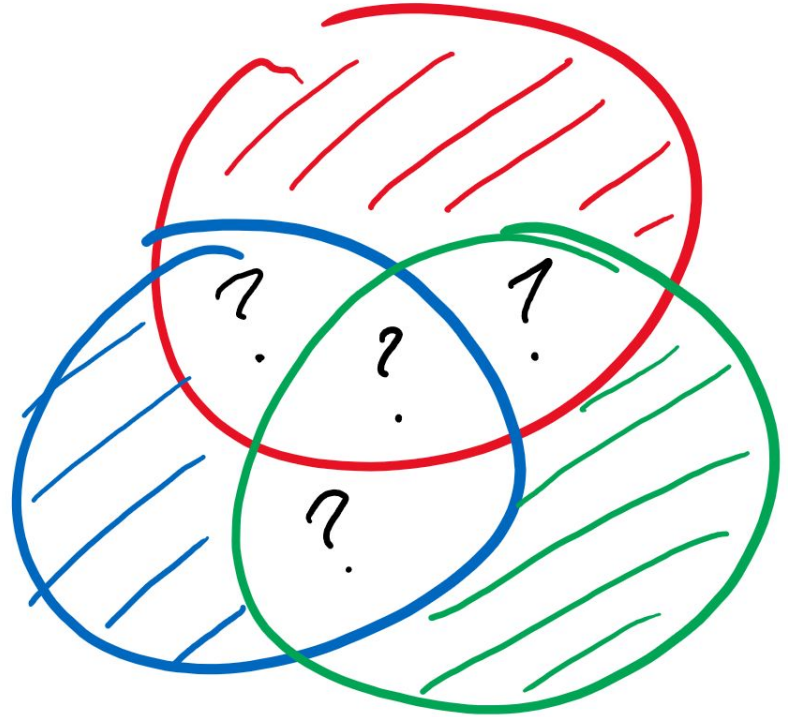
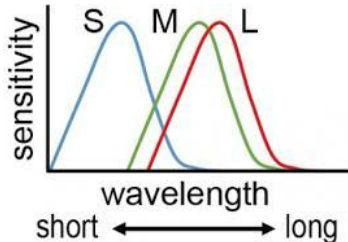
Primary colors?

Our eyes have “rods” and “cones”

Rods detect how “bright” something is

Different colors excite different zones in cones, can you guess which colors?

- Red, blue, green



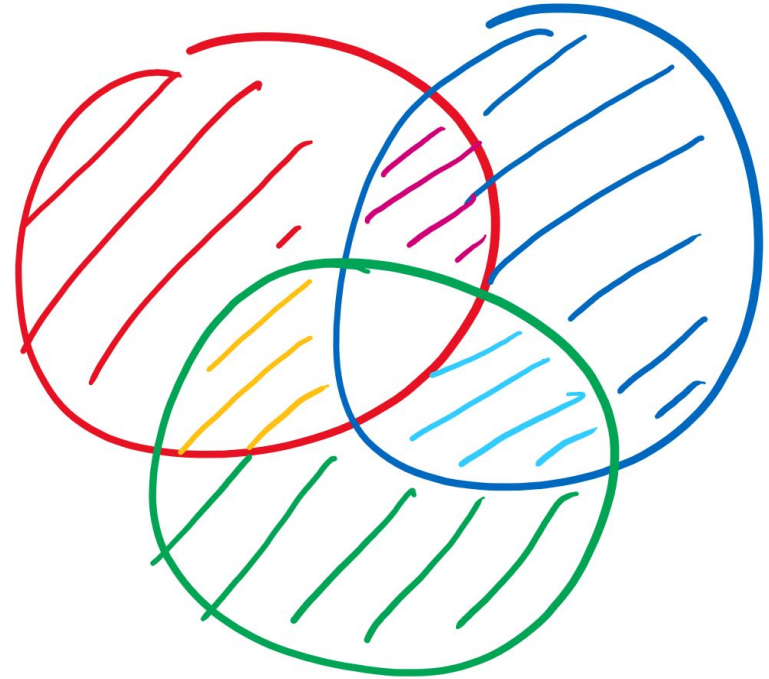
When colors interact

All colors together make white!

Any two “primary” colors of light make a “primary” color of paint

Why?

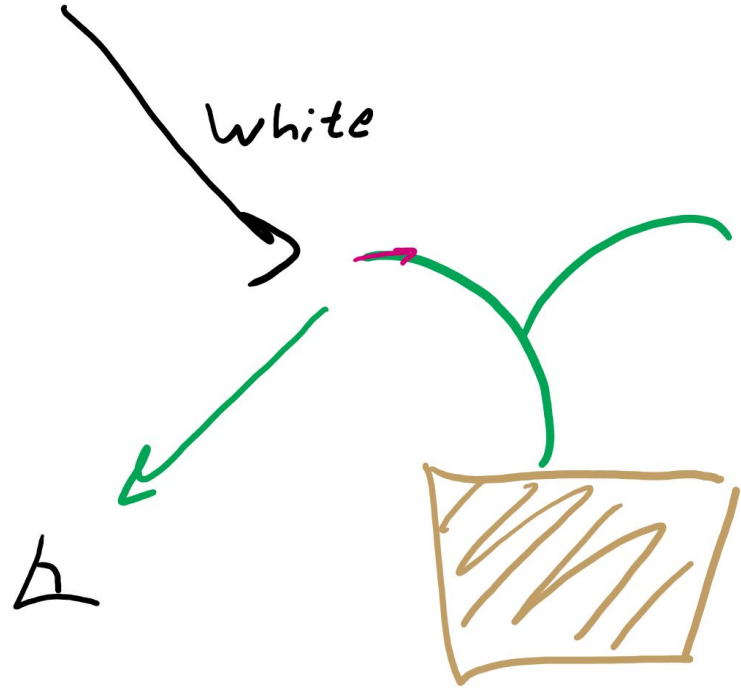
- What color do we get when we take *away* red from white?
- What if we took away blue?
- Green?



Why we see color

Objects absorb or reflect different amounts of light.

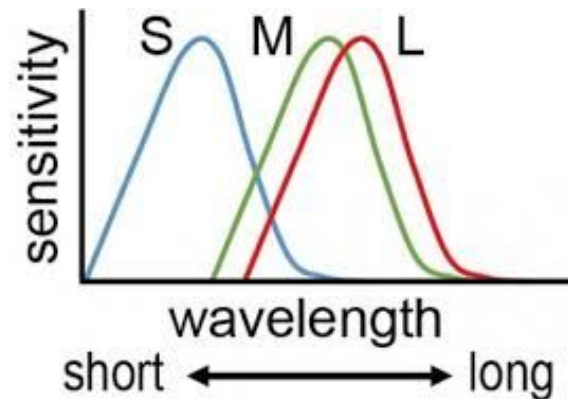
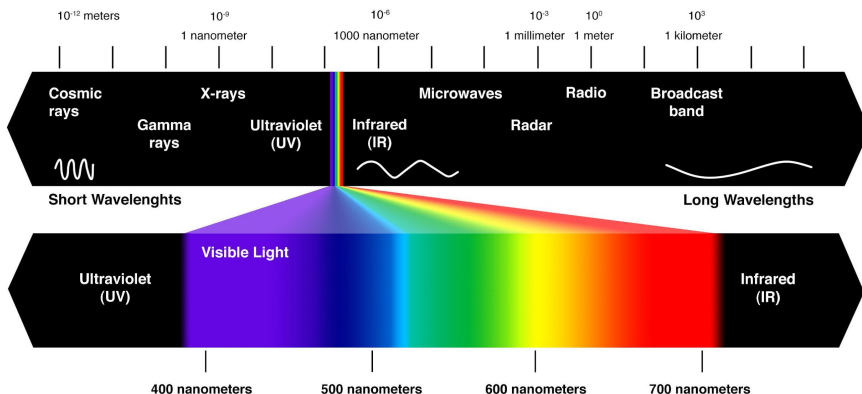
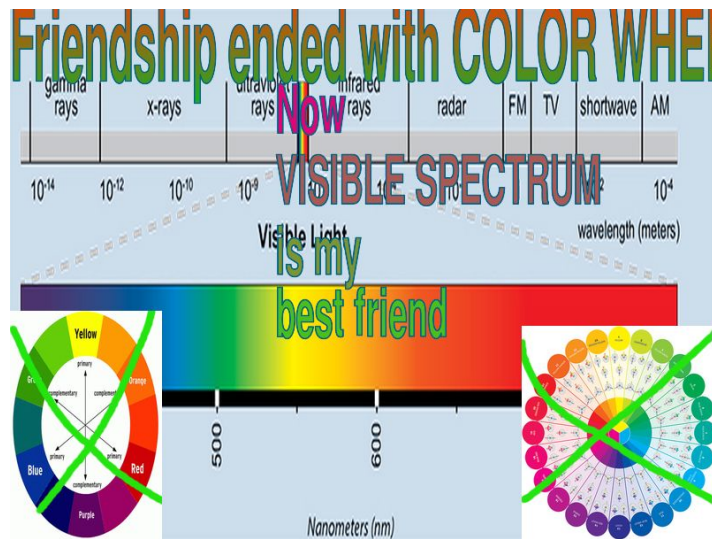
We only see the light that's reflected back at us.



Purple is a fake color hmph

Your art class lied to you; color doesn't exist in a wheel

“Purple” is just what our brain tells us we see when violet and red light interact



Lenses

What is a Lens?

What are some lenses that you know?

- Glasses
- Magnifying glass
- Camera Lenses
- Contact Lenses

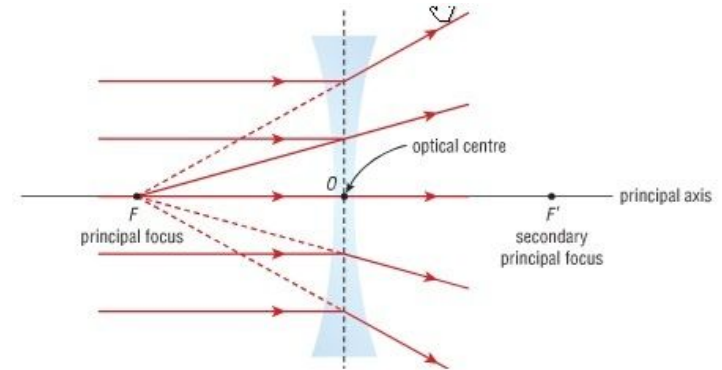
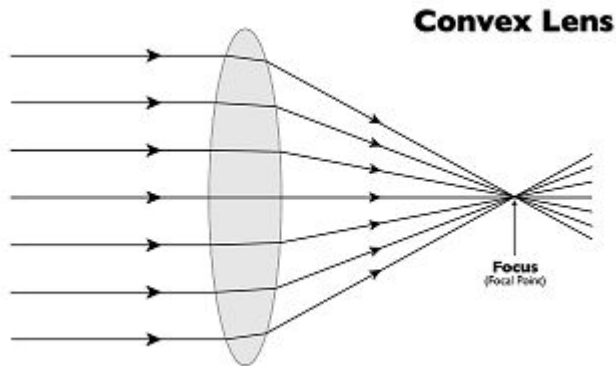
What is lens?

- “A lens is a piece of transparent material that is shaped so as to cause light rays to bend in a specific way as they pass through it, whether that means making the rays converge to a specific point or to diverge as if from a specific point.”

Focus?

“A focus, also called an image point, is the point where light rays originating from a point on the object converge”

- Where all the light goes to
- Causes Magnifying glasses to create fires
- Can also be a point where light doesn't go to



Example Analysis

Glasses:

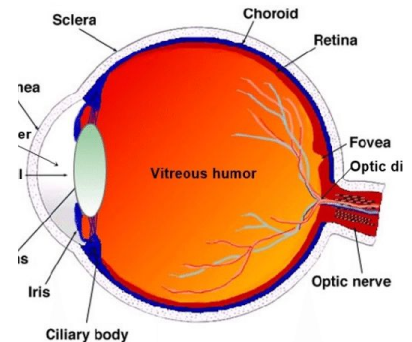
- Light should be focused by Cornea and Lens (the part of the eye is actually called lens) onto the Retina
- If any of those doesn't work properly, glasses help focus light on the retina

Magnifying glass:

- Focus the object so it looks at its largest before the focus

Cameras:

- Focus the light on a single point- Better Image



Why?

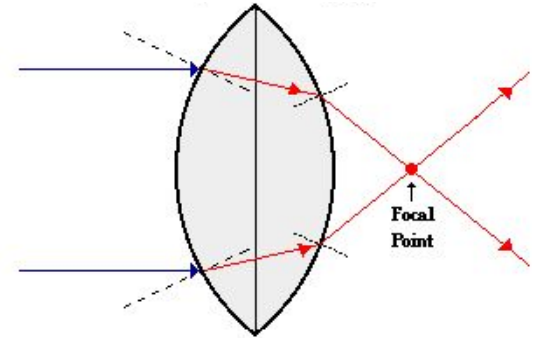
Any guesses?

Refraction!!!

- Light refracts due to the glass surface
- They change its direction so all light goes to one point

Although to refract the lens needs thickness...

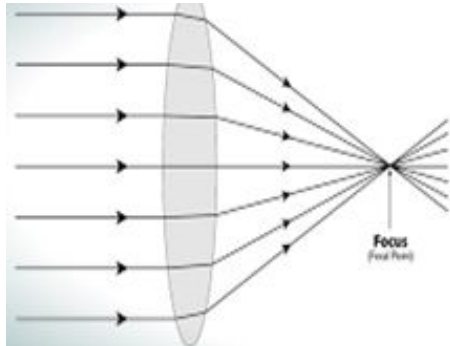
- Assume they are infinitely thin but still focus light
- This is perfect physics world :)



Types of Lenses

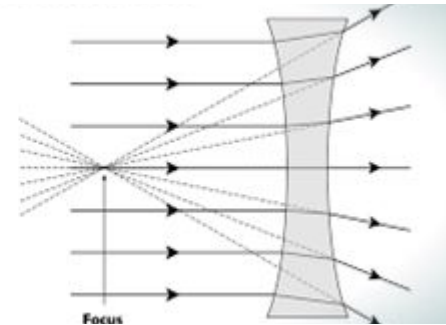
Concave:

- Glasses
- Magnifying Glass
- Focus is on the opposite side of object
- What does that mean?



Convex:

- Microscopes
- Telescopes
- Focus is on the same side as the object
- What does that mean?



Lens Diagram Terminology

Object: Thing being refracted through lens

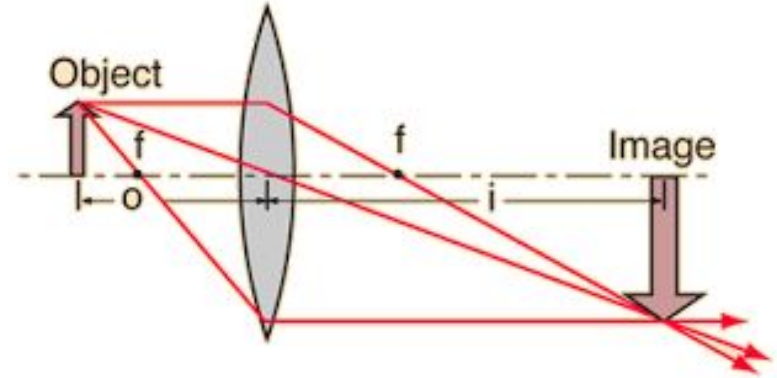
Image: What the object is seen as

- Real Image: The light comes from “real” rays
- Virtual Image: Comes from rays that aren't there

Principal axis: Line perpendicular to the lens through the center of the lens

Lens diagrams will often include $2f$ as well as f . $2f$ is very important as well.

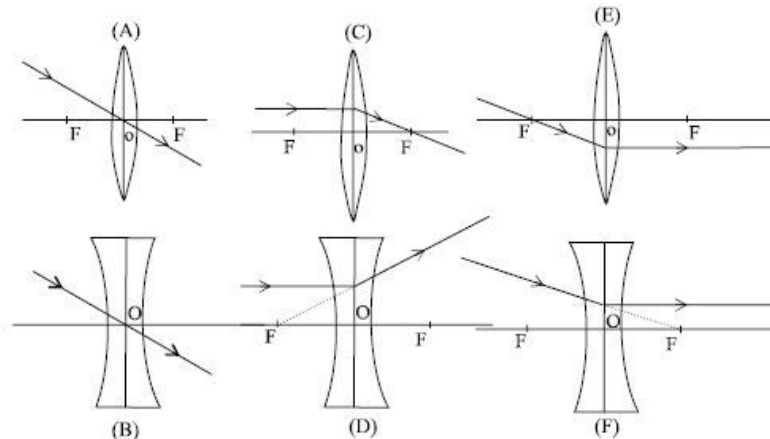
Size?



Rules of Lens Diagrams

Principal axis: Line perpendicular to the lens through the center of the lens

1. Rays Parallel to the Principal axis will pass through the focus
2. Rays passing through the focus will become parallel to the principal axis
3. Rays passing through the center will not change direction

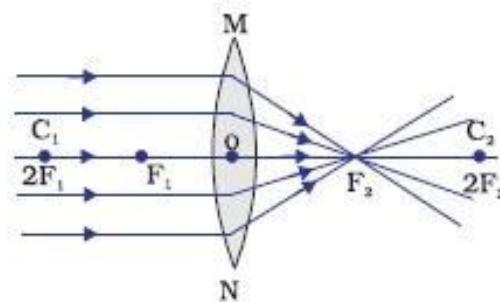


Converging lenses

Cases of Lenses 1

Case 1: Object at infinity

- Since the object is at infinity, rule 1 applies to all of the light
- All light must converge to the focus
- Image is non existent since it has size 0

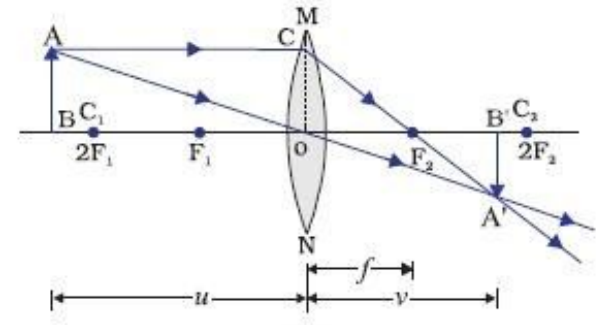


Case (i) Object at infinity

Cases of Lenses 2

Object is between infinity and $2f$

- Ray perpendicular goes through focus
- Ray through center goes straight through
- Ray through focus goes parallel
- Smaller image
- Flipped image

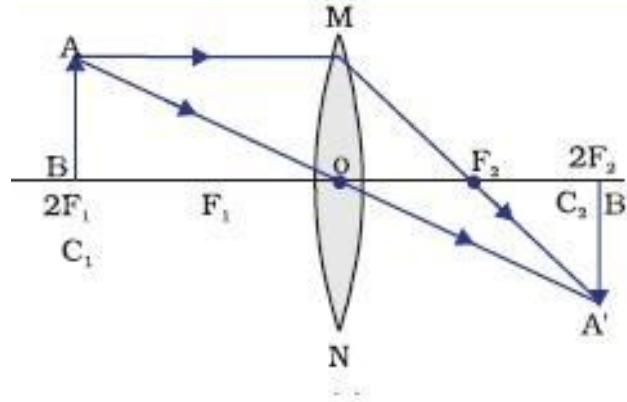


Case (ii) Object at beyond $2f$

Cases of Lenses 3

Object is at $2f$

- Ray perpendicular goes through focus
- Ray through center goes straight through
- Ray through focus goes parallel
- Same size!
- Flipped image

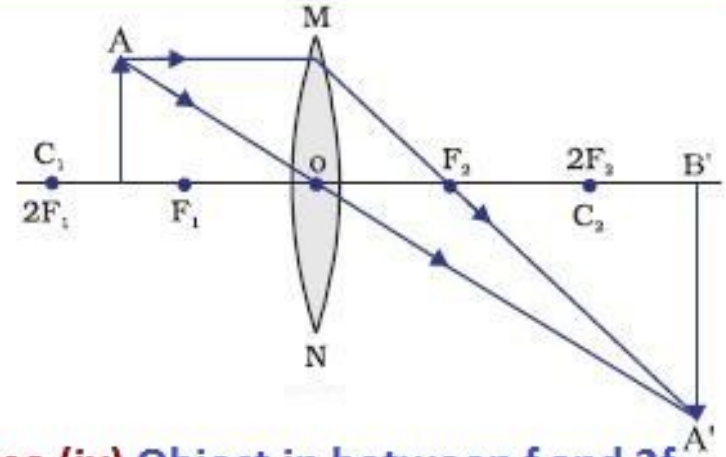


Case (iii) Object at $2f$

Cases of Lenses 4

Object is between f and $2f$

- Ray perpendicular goes through focus
- Ray through center goes straight through
- Ray through focus goes parallel
- Increased size!
- Flipped image

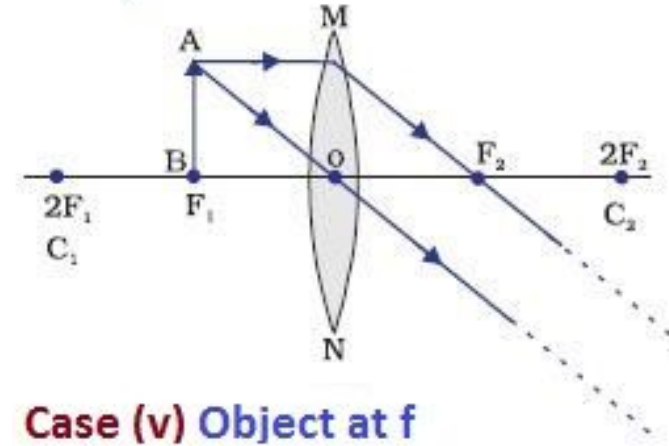


Case (iv) Object in between f and $2f$

Cases of Lenses 5

Object is at f

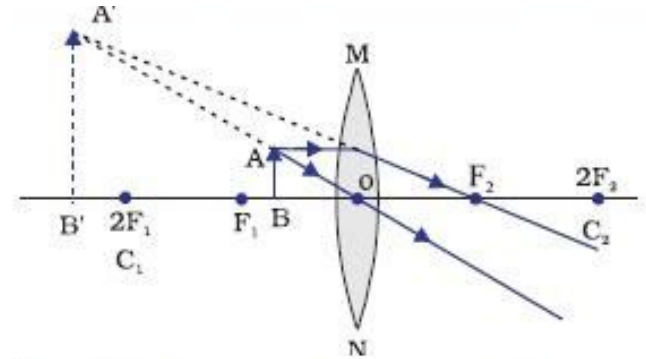
- Ray perpendicular goes through focus
- Ray through center goes straight through
- Ray through focus goes parallel
- No image!



Cases of Lenses 6

Object is between the lens and f

- Ray perpendicular goes through focus
- Ray through center goes straight through
- Ray through focus goes parallel
- Image is formed on the same side as the object!
- Virtual image
- Not Flipped



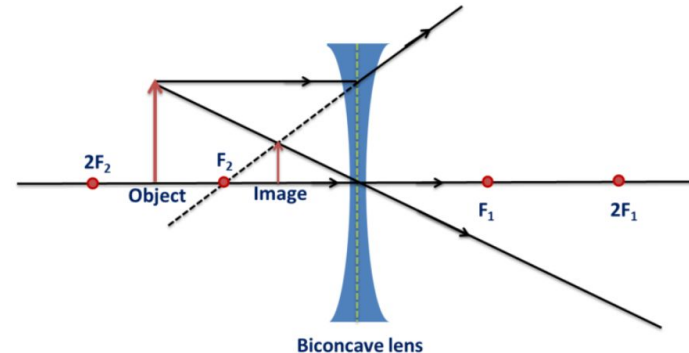
Case (vi) Object distance $< f$

Diverging lenses

Cases of Lenses 1

Literally the only cases lulw

- Image always virtual and smaller
- If all the rays come from infinity, no rays go through the center
 - Image is a point at F_2
- The closer the object gets, the larger the image becomes, and the location of the image gets closer to the lens



Review

What is a lens?

What is the focus of the lens?

Why do lenses bend light?

If an object is at exactly $2f$...

1. How large is the image compared to the object?
2. Is the image real or virtual?
3. Is the image flipped or not flipped?