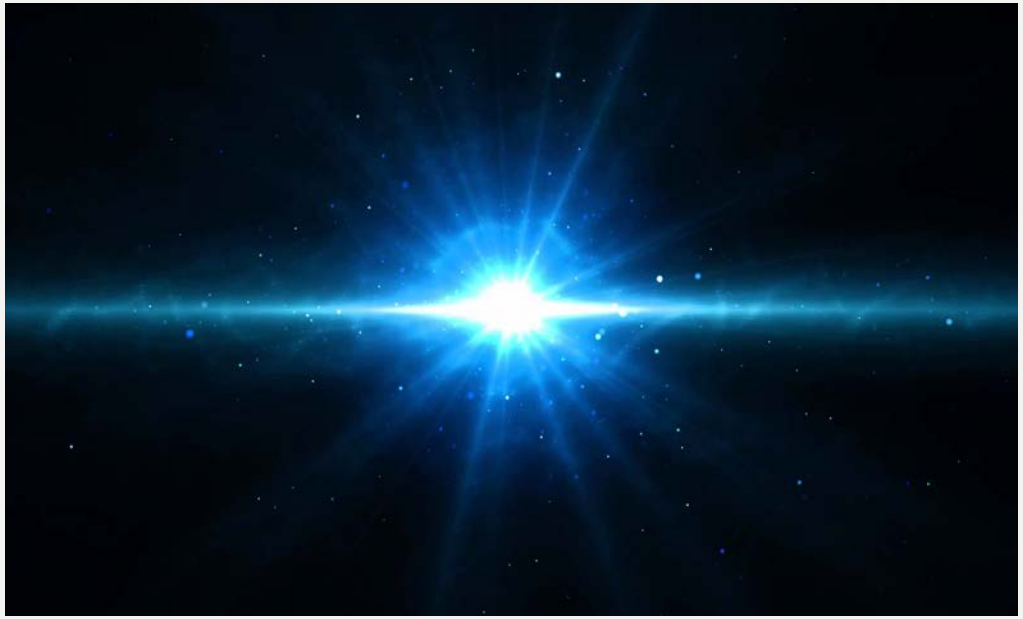
INTRODUCTION **TO** LIGHT

CHAPTER 1: THE ADVENTURE OF LIGHT

- 300,000 years after the Big Bang, when all the particles were cool enough, light final found enough space to travel.
- Atoms were formed! Light then could travel through a fairly large distance. The oldest light we have received is 13 billion years old.

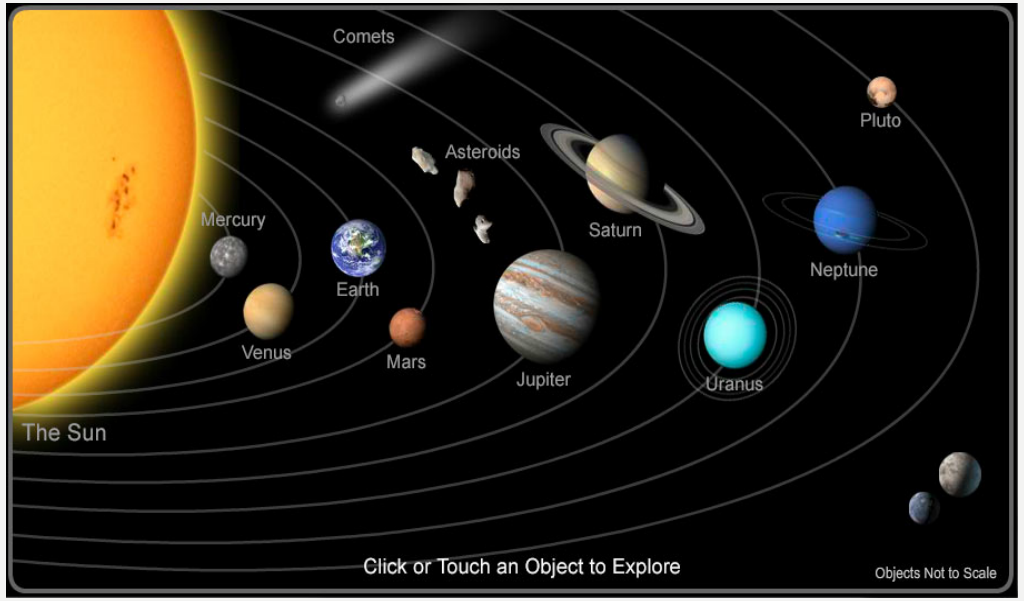


The Big Bang

i.ytimg.com/vi/r-lHneE3cQY/hqdefault.jpg

ACT LIKE A BOSS

- Light is so charming, everything wants to shine. But light only allow those stars who have enormous amount of energy to shine.
- About 4.5 billion years ago, light authorized the sun to illuminate.
- Light is so generous, he brings the energy from sun to every planet in solar system.



Solar system

structureworld.work/wp-content/uploads/2016/02/solar-system-840x510.jpg

YOU ARE WELCOME, EARTH.

- Two billion years ago, light found a planet has water. He gives the energy gained from sun to plants that evolved billion years later, to make oxygen and carbohydrates from carbon dioxide and water. Large amount of oxygen was created to allow oxygen-breathing life to evolve on earth.

Earth

lh3.ggpht.com/Ay-RJvUJCltSc8GifC8CDASKR-PYdvjbb00UfRAnHb0uQ9QBWE9Jwcr5l2vc-BCnug=w300

CHAPTER 2: MANKIND LIGHT

campfire

http://ocdn.eu/images/pulscms/MDQ7MDA_/44fd368eb02c7e6c2907e2592be72733.jpg

Electricity

http://mothergold.org/wp-content/uploads/2015/10/innovations.png

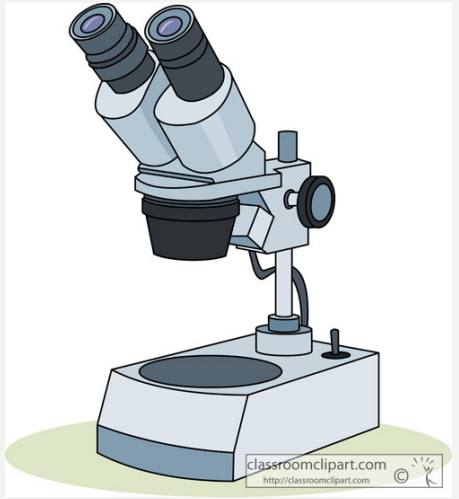
LED

http://ecx.images-amazon.com/images/I/71OL2ha5QSL._SL1500_.jpg

CONTROL OF LIGHT

https://secure.img1.wfrcdn.com/lf/maxsquare/hash/1261/16696516/1/Louis-Wall-Mirror-60010.jpg

http://g01.a.alicdn.com/kf/HTB1Gf_yKVXXXXX6XFXXq6xXFXXX2/Stunning-Sound-and-Light-Star-Wars-Lightsaber-56-CM-Jedi-Knight-Lightsaber-Cosplay-Darth-Vader-Scalable.jpg_640x640.jpg



http://clipartfreefor.com/cliparts/microscope-clipart/clipart1_microscope-clipart_08.jpg

http://wallpaperswide.com/cartoon_telescope-wallpapers.html

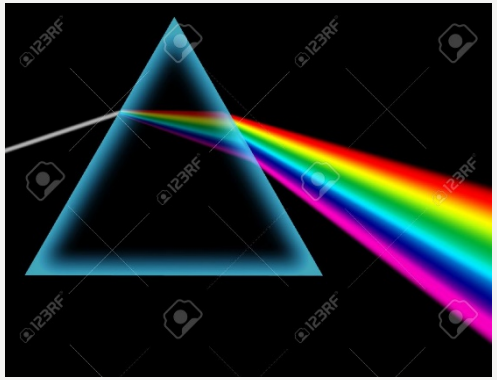
http://www.allmacwallpaper.com/get/Retina-MacBook-Pro-15-inch-wallpapers/Artistic-Flowers-Glasses-2880x1800/1035-8.jpg

CHAPTER 3: OBSERVATION OF LIGHT

- Tycho, 1572, observed an unexceptional bright star. This subverted the old universe model
- Galileo, 1609, invented Galilean telescope. Human started to explore the universe.
- Leeuwenhoek, 1673, invented microscope. The microscopic world appeared in front of human eyes.

OBSERVATION OF LIGHT

- Newton, 1666, Prism light decomposition.
- Aristotle, Pinhole imaging,
- Nicéphore, 1826, using Pinhole imaging invented camera.

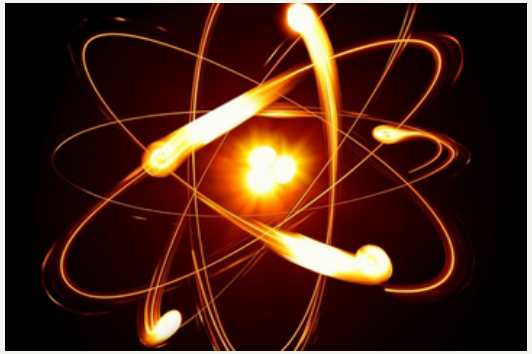


http://previews.123rf.com/images/yakobchuk/yakobchuk0612/yakobchuk061200008/653227-Decomposition-of-white-light-on-seven-colors-Stock-Photo-prism-light-spectrum.jpg

http://farm3.static.flickr.com/2779/4472252560_e1a941812d_b.jpg

CHAPTER 4: THE ESSENTIAL OF LIGHT

- Light can be treated as a kind of electromagnetic waves and have the properties of wave.



http://3.bp.blogspot.com/-66h__luftrg/Uwt1Pli6eUI/AAAAAAAAAQw/DheRcRoWeMg/s1600/atom-electrons.jpg

THE PROPERTIES OF LIGHT

- Interference
- Diffraction
- Polarization

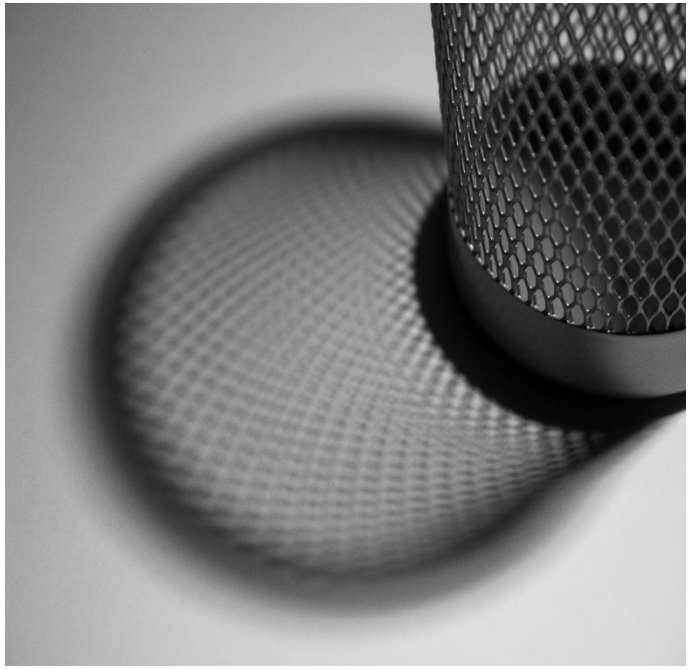
Interference

What is interference

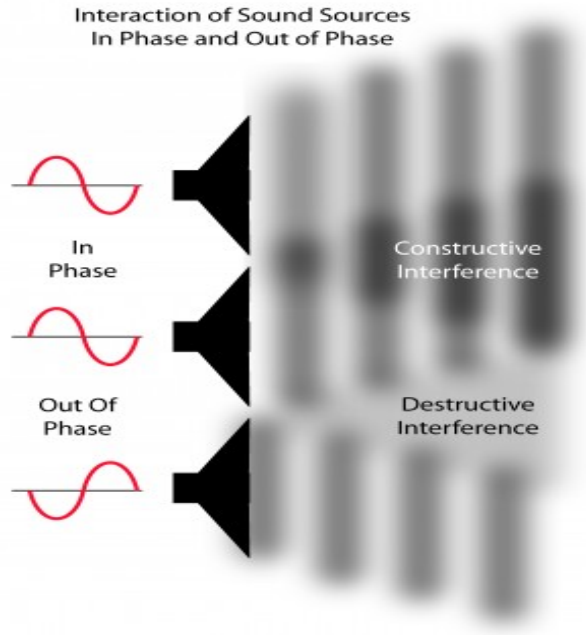
- When two waves encounter with each other, the amplitude of the wave will either increase, decrease, or remain same. This phenomenon is call interference

- Interference implies the interaction of two waves.

Examples

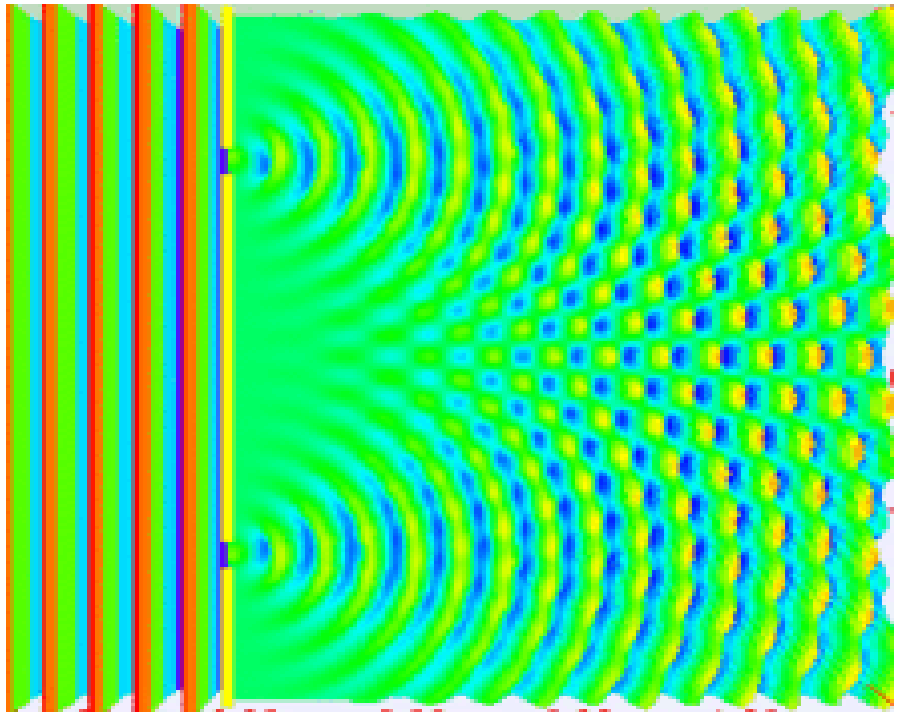


https://mike-baker.net/2013/04/08/interference/



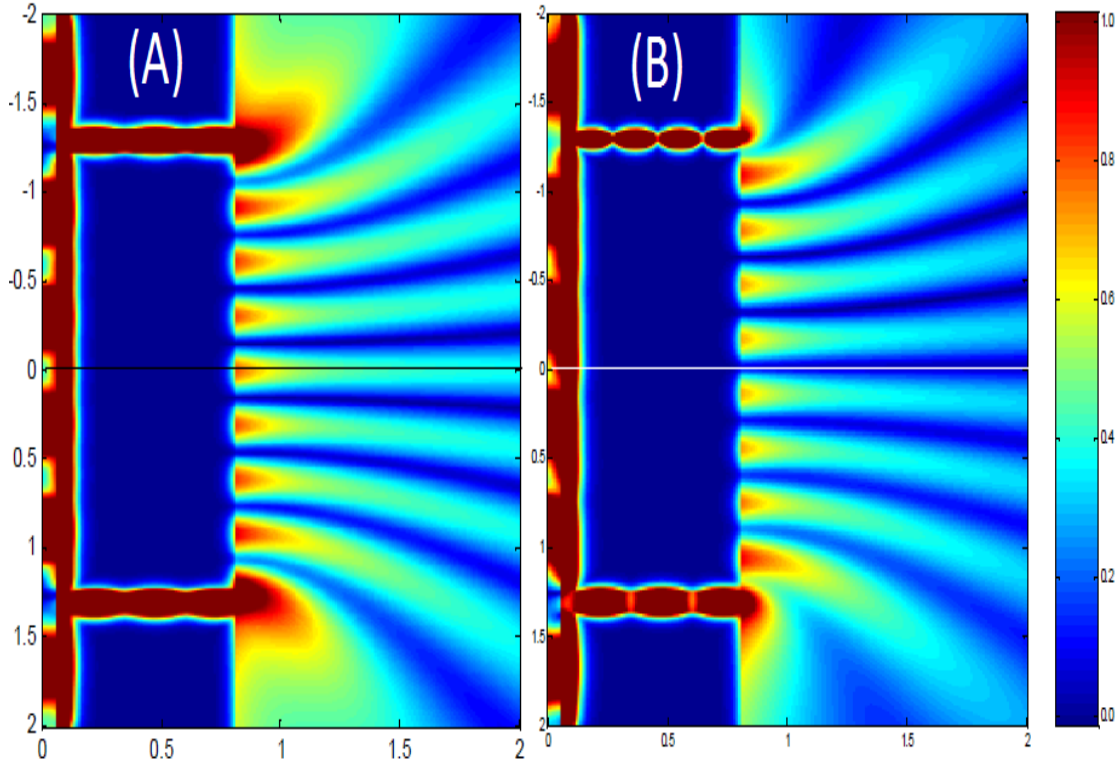
http://www.ctgclean.com/tech-blog/2011/10/ultrasonics-sound-interactions-of-sound-waves/

Double slit experiment of light



https://medium.com/the-physics-arxiv-blog/when-classical-universes-collide-the-result-is-quantum-mechanics-say-physicists-acfb003f3fa6#.cbq4jr8y3

The result

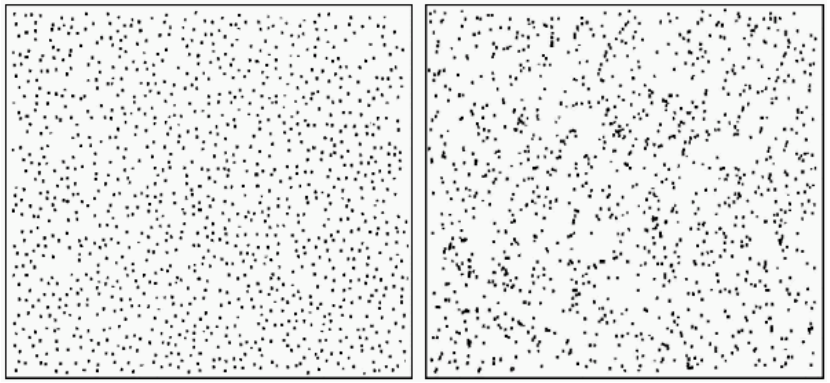


Bach, Roger; et al. (March 2013). "Controlled double-slit electron diffraction".

Particle

Take a basketball as example

- The distribution is random
- Any place is possible to have some particle



https://telescoper.wordpress.com/2009/04/04/points-and-poisson-davril/

Wave

Take light wave as an example

- The distribution is not random
- Some place can have no light presented.

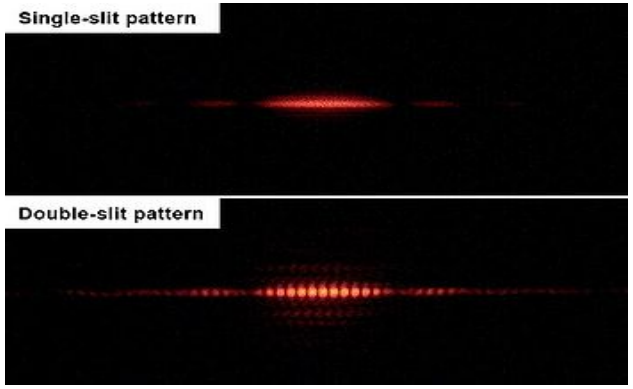
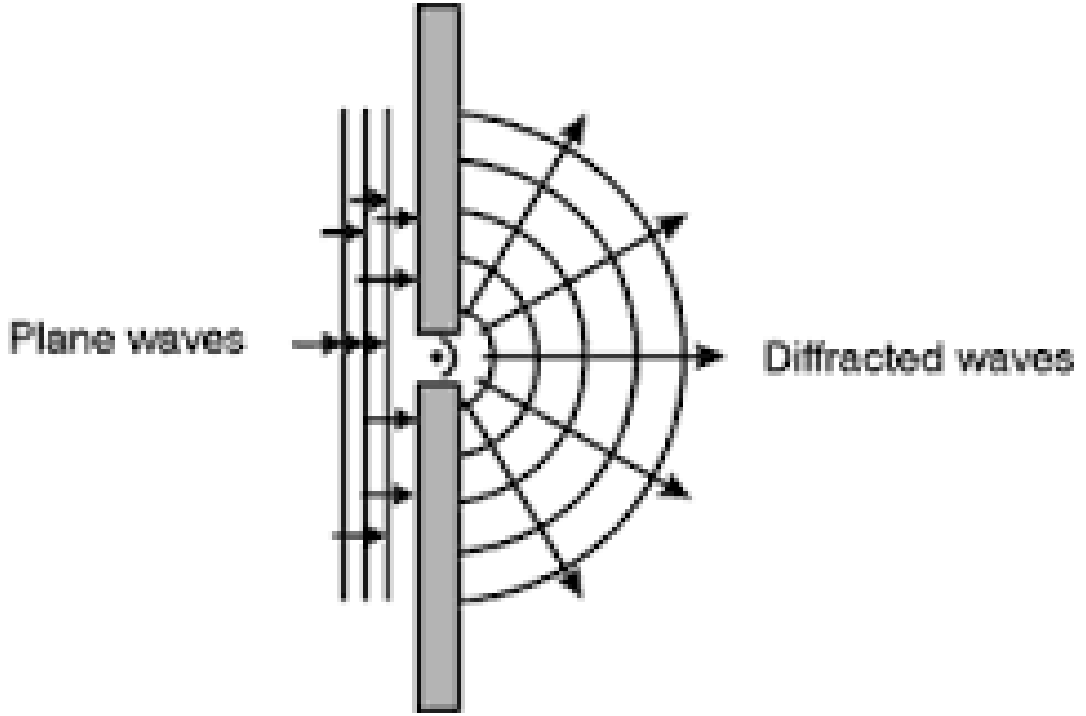


Photo credits: Creative Commons, Jordegette

Diffraction

What is diffraction

When a wave encounters a hole, the wave bends around the slit on the other side. This phenomenon is call diffraction.



Regents Physics Quick Review – Mechanics. N.p.: n.p., n.d. PDF.

Examples

http://dcdv.zol.com.cn/338/3389191.html

http://photovide.com/amazing-examples-sky-photography/

Diffraction reveals that the light is wave-like

Particle

Take a basketball as example

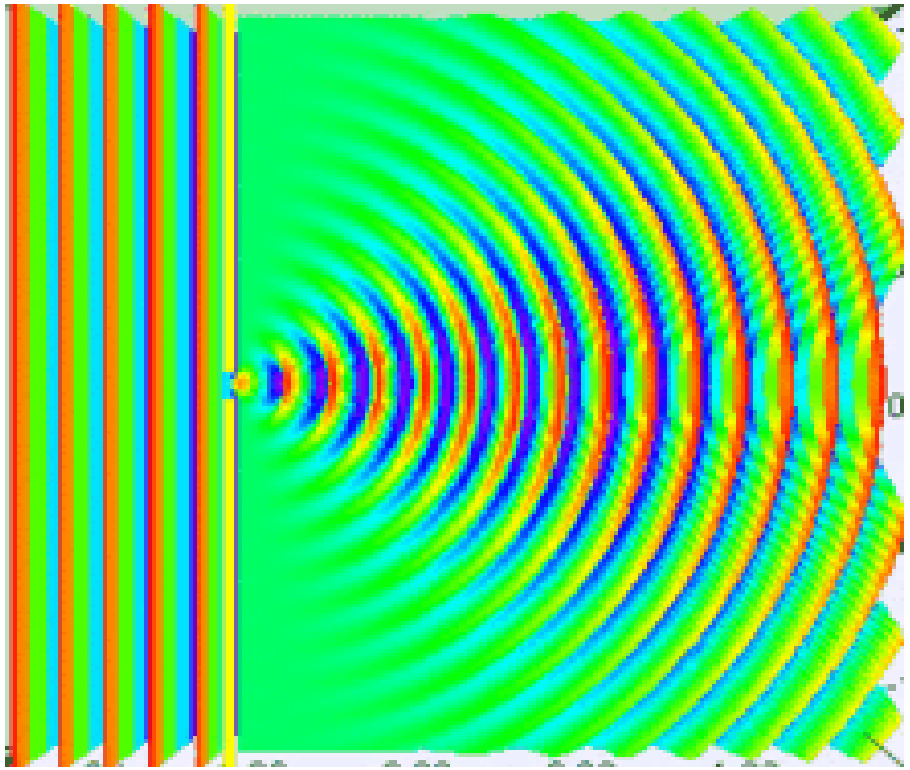
- When the basketball hits a slit, the ball either goes through or bounces back, the shape does not change.

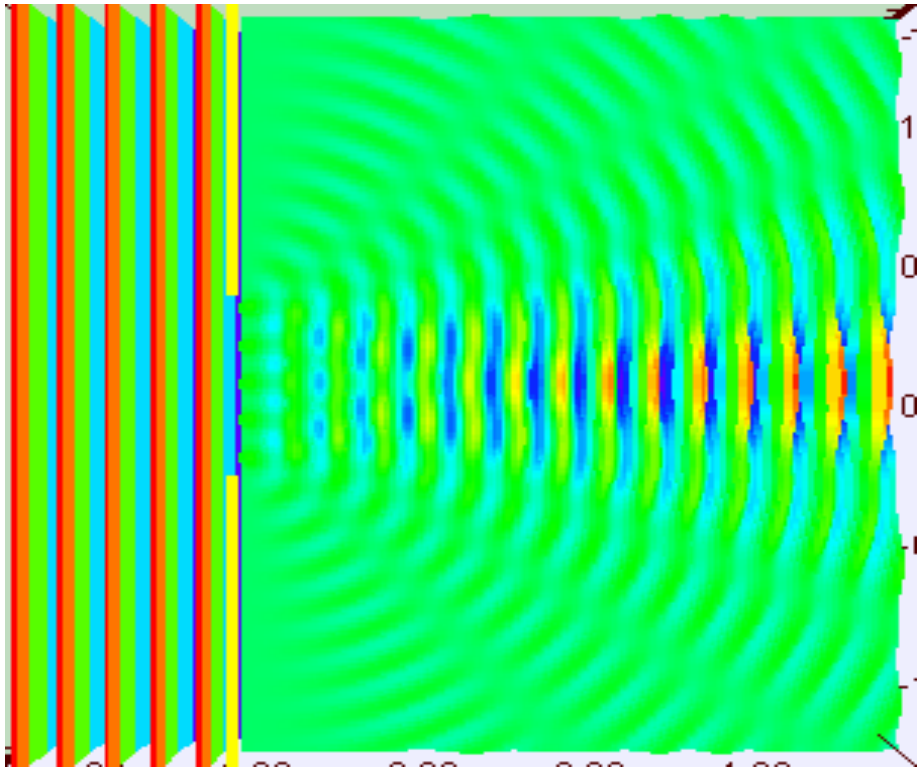
Wave

Take the wave in water as example

- When the wave hit a slit, a part of wave go through, the shape of wave changes.

Single slit diffraction of light





http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-s079-nanomaker-spring-2013/labs/MIT6_S079S13_slides02.pdf

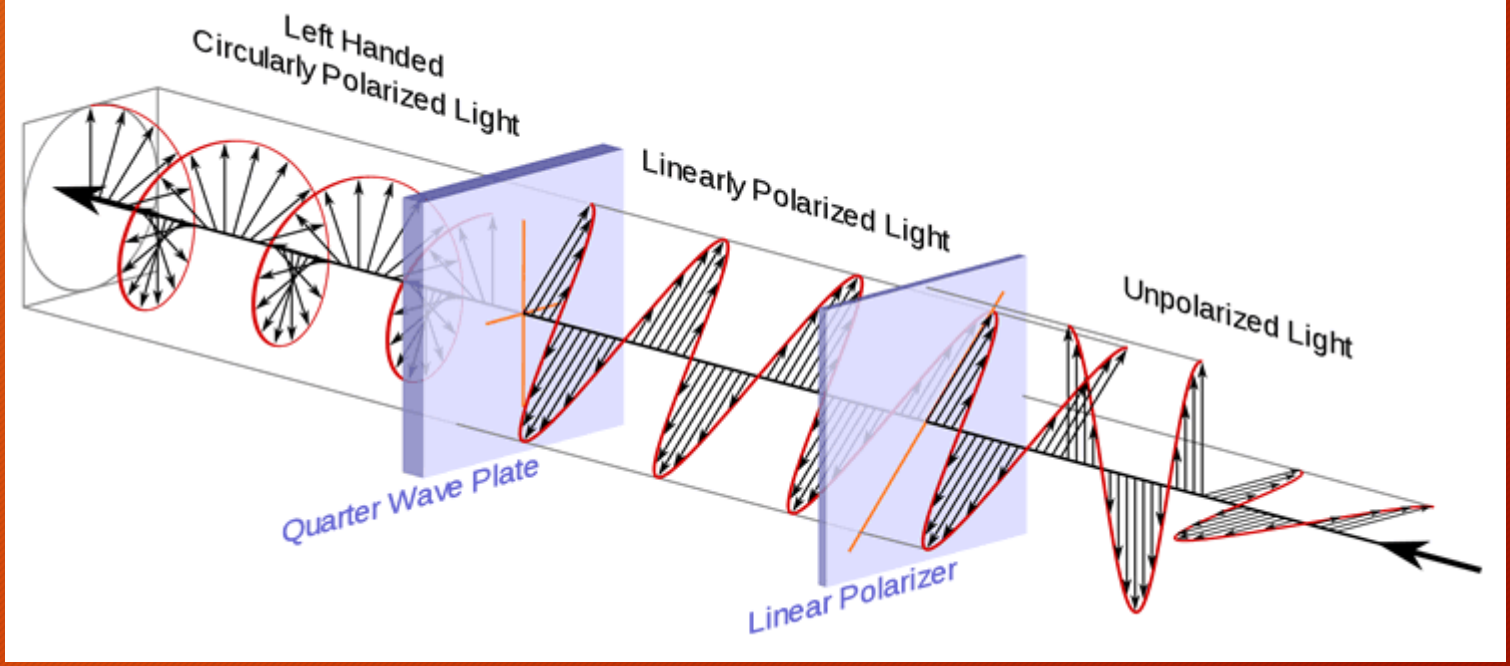
What difference you have observed?

THE SIZE OF THE HOLE IS ESSENTIAL

Polarization

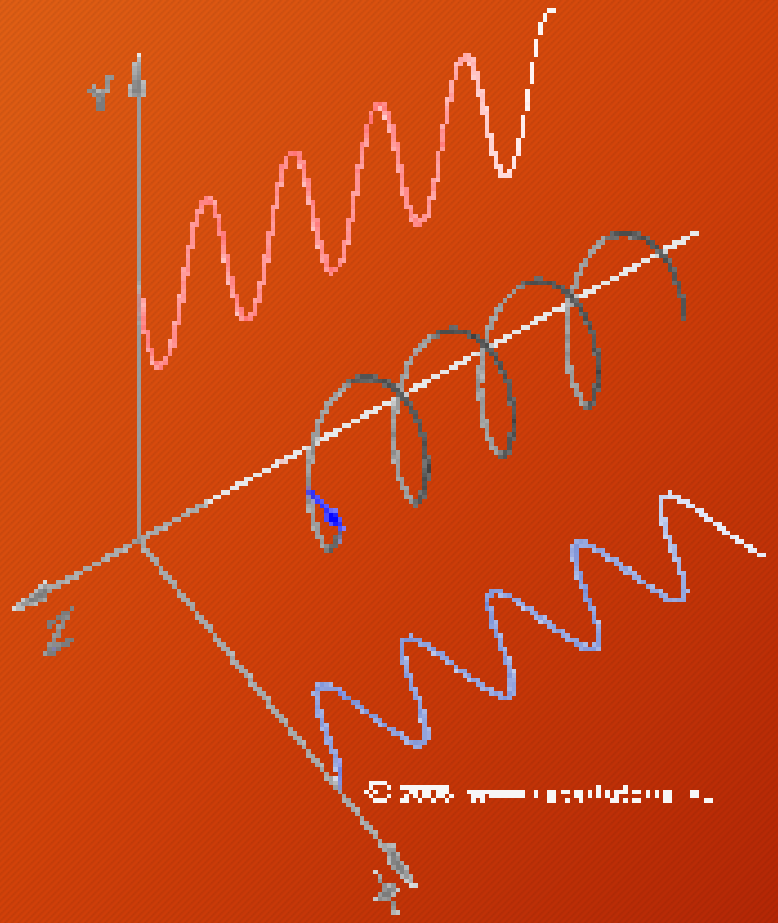
What is polarization

Wave is a vector quantity, which means one of the component is direction. Polarization is the direction that wave can oscillate. The oscillation is always orthogonal to the direction that the wave travels.



https://id.wikipedia.org/wiki/Berkas:Circular.Polarization.Circularly.Polarized.Light_Circular.Polarizer_Creating.Left.Handed.Helix.View.svg

Two types of polarization

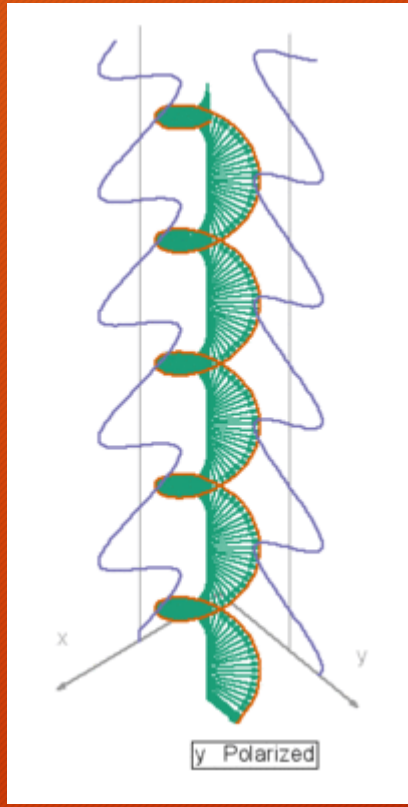


https://commons.wikimedia.org/wiki/File:Rising_circular.gif

Linear

https://commons.wikimedia.org/wiki/File:Polarisation_rectiligne.gif

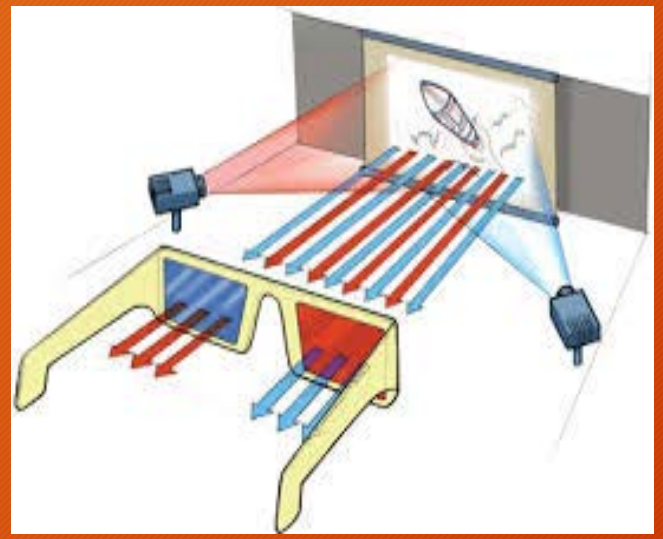
Circular



https://commons.wikimedia.org/wiki/File:Wave_Polarisation.gif

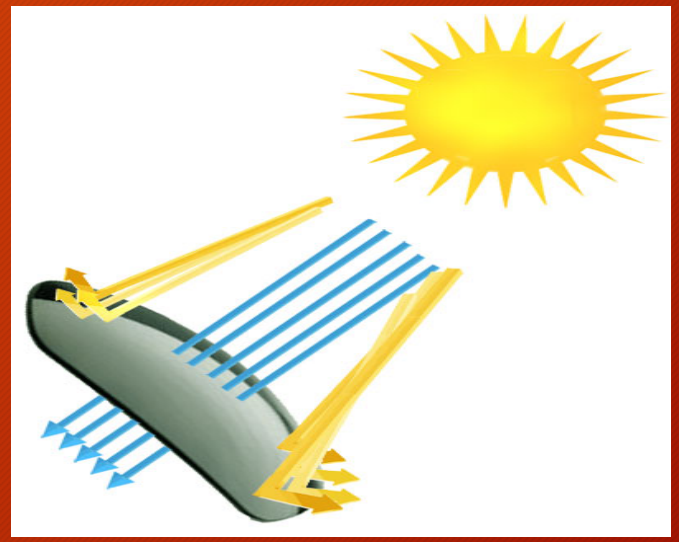
Examples of Polarization

3-D Glasses



http://www.wonderoftech.com/3d-technology-coming-soon-from-nintendo/

Sun Glasses



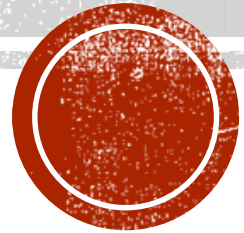
https://www.thesunglassfix.com/What-are-Polarized-Lenses

Polarized sky photograph

https://commons.wikimedia.org/wiki/File:CircularPolarizer.jpg

Non-Polarized Polarized

SUNLIGHT AND SPECTRUM



FACTS OF SUNLIGHT

- Radiation
- A photon Takes 8.3 minute to go from sun's surface to earth
- The same photon needs 100,000 years to reach sun's surface from the center of sun.
- Incredible amount of energy is carried by sunlight.
- Can be used by plants for photosynthesis.
- Has temperature.
- Part of sunlight is visible.
- Part of sunlight is not visible.

THE VISIBLE PART

- How many colors can we see from sunlight?
- Which one is your favorite?
- Which one is the hottest?

OF COURSE 7 COLORS

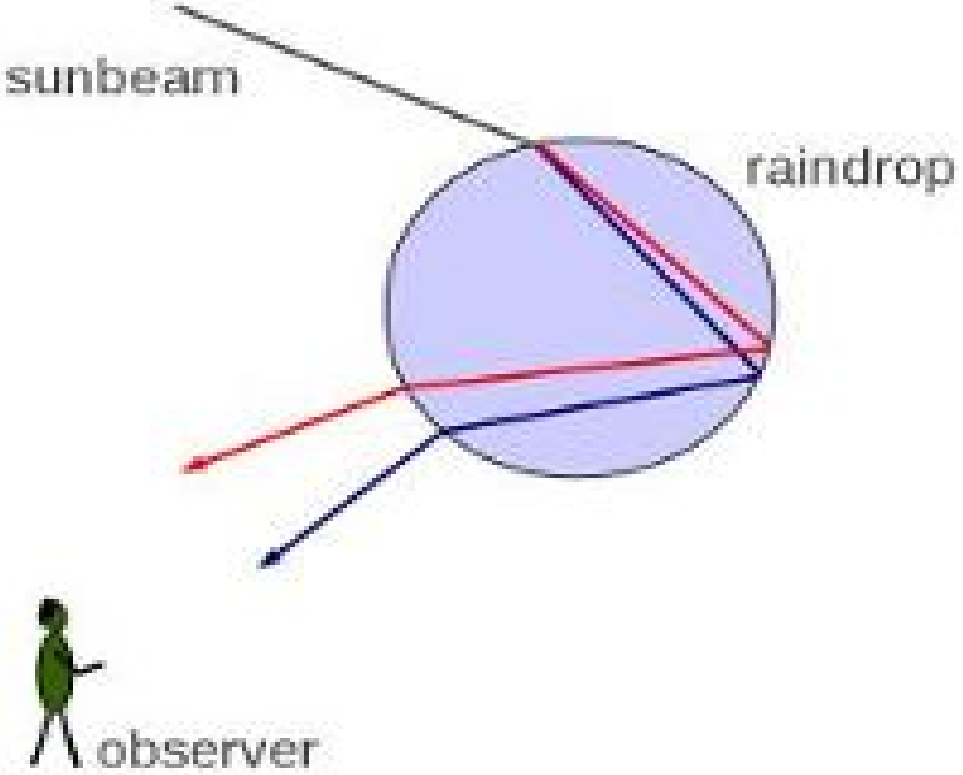
http://i.vimeocdn.com/video/542849673_1280x720.jpg

NEWTON'S EXPERIMENT

http://media.gettyimages.com/photos/isaac-newton-english-mathematician-physicist-and-astronomer-author-of-picture-id89860754

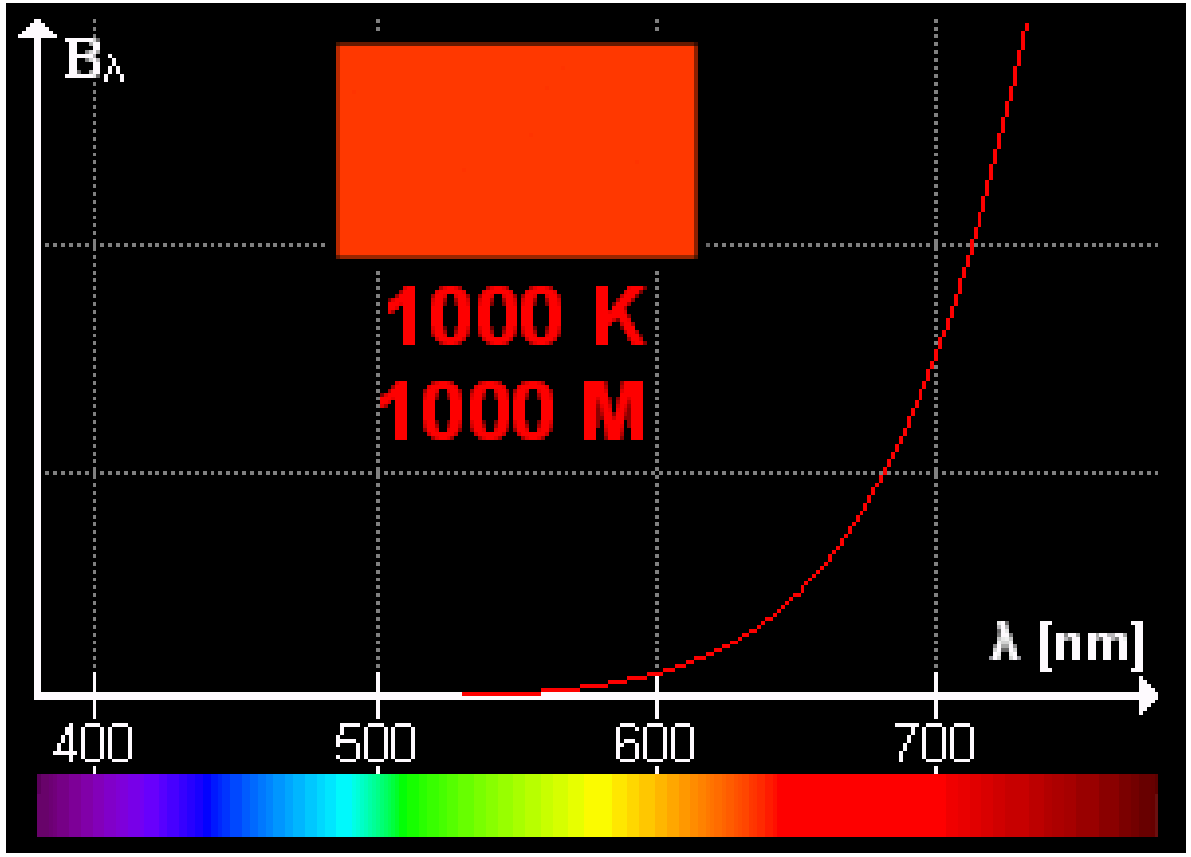
THE REASON BEHIND RAINBOW

Lights with different wavelength will have different refraction angle from air to rain drop



https://lh3.googleusercontent.com/mgDOW8JI5OdZTi_hCMWkLa-ayOTgKQ_hrP3uGOGAyw69SldLjHEV2CX-0bEZ8Hgirc4ynA=s94

THE HOTTEST COLOR:

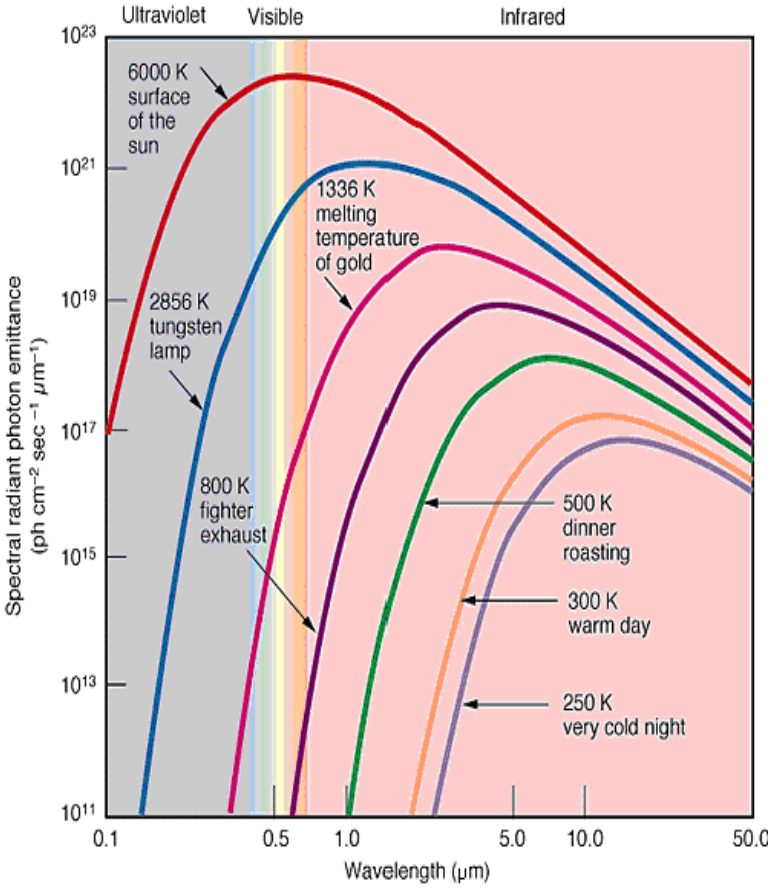


https://upload.wikimedia.org/wikipedia/commons/thumb/2/21/Black_body_visible_spectrum.gif/120px-Black_body_visible_spectrum.gif

BUT…

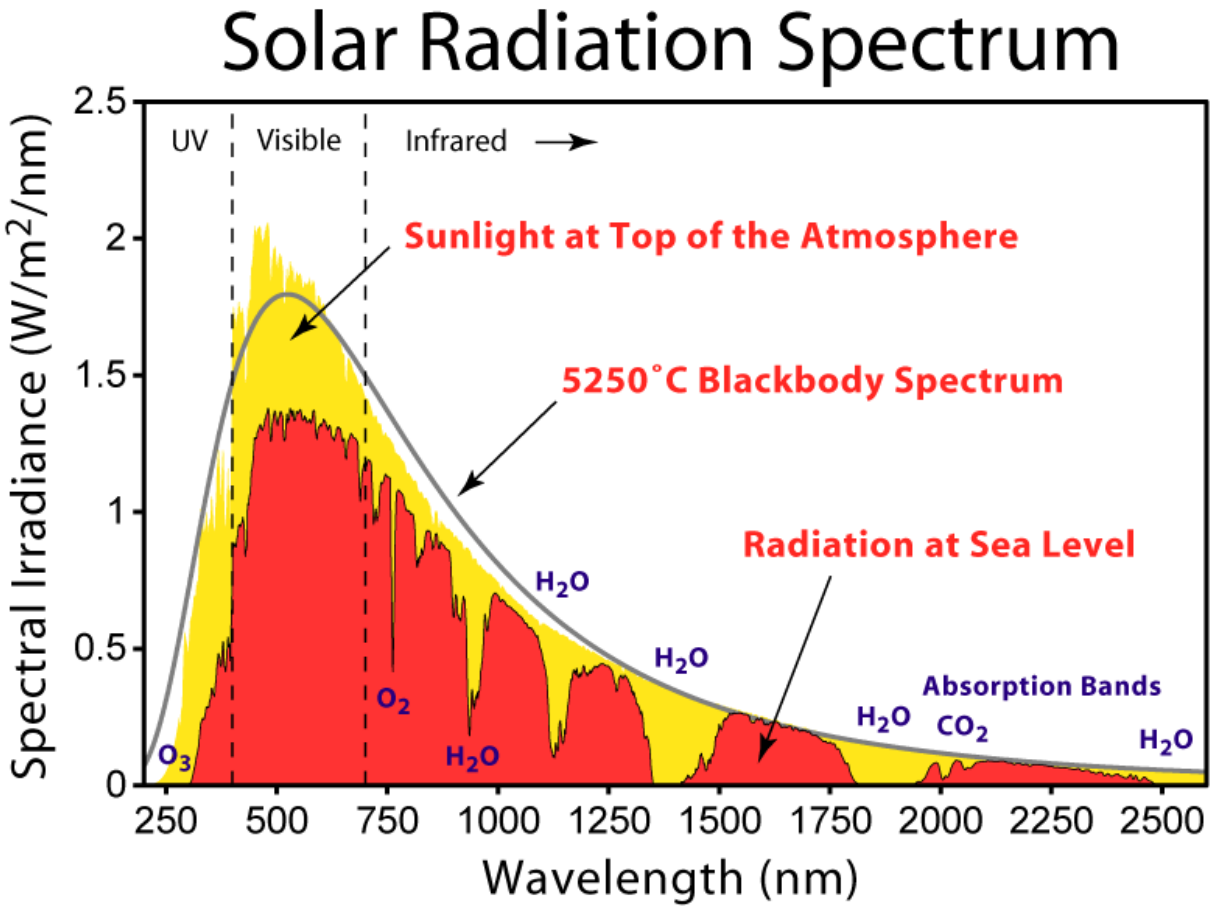
- The seven colors are the way that people divide the visible range. It actually has infinity many kinds of color

- The hottest color does not mean the blue sunlight is the one that has highest temperature. Every beam of sunlight has similar radiance for each visible color. According to the picture on the right, we can see that the temperatures are pretty much same; especially when the light reaches earth. But from experiments, the red color light carries most heat.



http://www.adept.net.au/news/newsletter/20
0802-feb/resources/ir-radiation.png

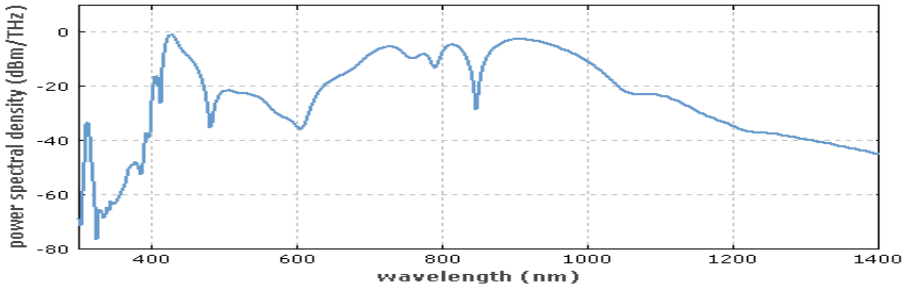
THE COMPLETE SPECTRUM



http://media.showme.com/files/310126/pictures/thumbs/542001/last_thumb1354706976.jpg

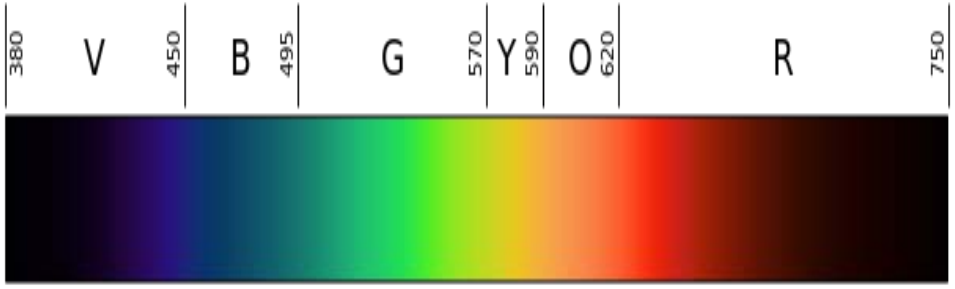
SPECTRUM

- The optical spectrum is the information about how the optical energy distributed over different wavelength.



Spectrum in general

https://lh3.googleusercontent.com/-PhATLW4GoiRCFT5437Ni433sMImvmCK4jgX9YMannv9_3PBTMCSxSWdHadySU3ifQ_sMpg=s170



Visible spectrum

https://2ch.hk/un/src/387719/14582527491531.png

UNSEEN LIGHT

TWO TYPES OF INVISIBLE LIGHT

- Ultraviolet
- Infrared

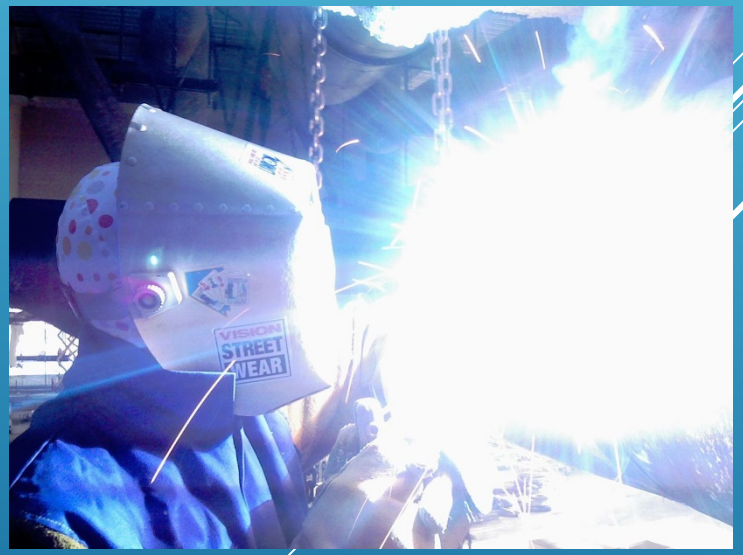
ULTRAVIOLET

Wavelength is shorter than then visible light, in between 10nm-380nm

Invisible here means human cannot see via naked eye

Damages human's skin and eye

Wildly used in label tracking and disinfection



Brainass. *Pipefitter Welder Kutzo*. Digital image. *Wikimedia Commons*. N.p., 06 Aug. 2008. Web. 27 Apr. 2016. <https://commons.wikimedia.org/wiki/File:Pipefitter_welder_kutzo.jpg>.

HOW WAS UV DISCOVERED

In the year 1801, Johann Ritter was experimenting with silver chloride, a material that will turn black under sunlight. He placed silver chloride in each interval of the visible spectrum he got from a glass prism.

He first found that blue light cause silver chloride to turn black more than red light did. Then he placed the silver chloride in to the region beyond violet, where no light could be seen by naked eye, but silver chloride displayed an intense reaction. This showed that the invisible sunlight exist beyond the violet region.

INFRARED

- **Wavelength is longer than then visible light, between 700nm-1000000nm**
- **Invisible here means human cannot see by naked eye**
- **50% of heating on earth is due to infrared**
- **Wildly used for heating and detecting**

File:Ir Girl. Digital image. *Wikimedia Commons*. N.p., 1 Feb. 2008. Web. 27 Apr. 2016. <https://commons.wikimedia.org/wiki/File:Ir_girl.png>.

HOW WAS IR DISCOVERED

In the year 1800, William Herschel was interested that how much heat carried bydifferent colors of the sunlight.

William used a glass prism to create a visible spectrum. He placed blackened bulbs in each color region to absorb heat and he found that the temperature of the bulbs increased from violet to red. William decided to measure the heat of the region beyond red. He found that this region had the highest temperature. This implied that the invisible sunlight exists beyond the red region.

Light in Space

http://wallpaperbeta.com/space_planet_galaxy_star_hd-wallpaper-272228

Let us try to answer two questions

Why is the sky blue during the daytime

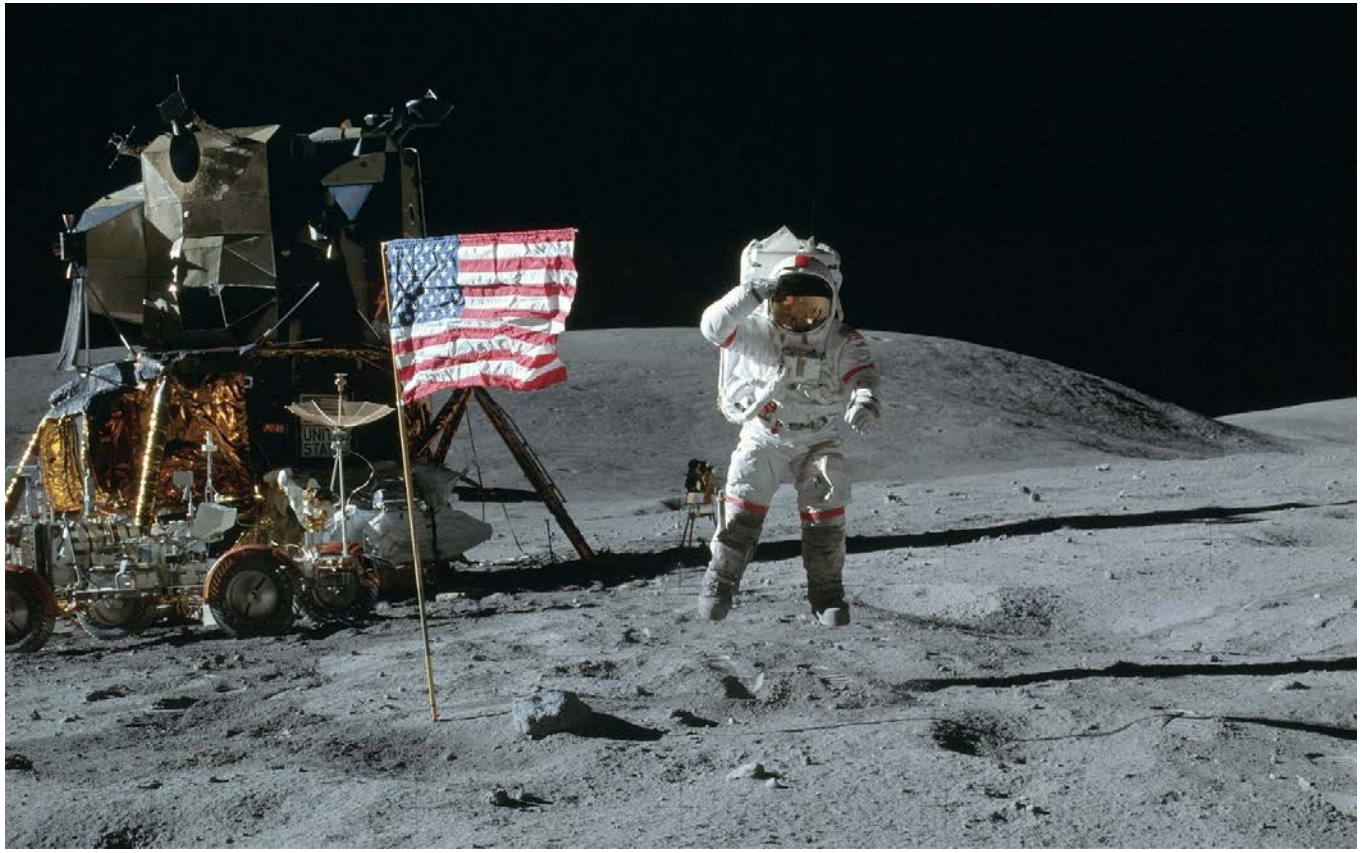
Why is space black

During daytime, sunlight hits the molecules in our atmosphere. The scattering process gives the sky blue color.

During nighttime, the sky is black because there is no light source like the sun.

But still, why is the space black?

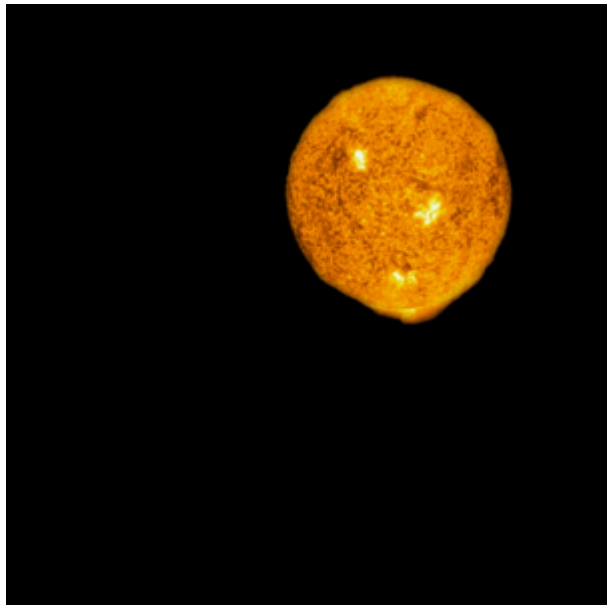
This is the view of space on the moon



http://www.ilcorvo.it/2016/01/28/come-spiegare-se-le-teorie-complottiste-sono-vere-risponde-la-matematica/

Olbers' paradox

If the universe was infinity large and infinity old, we can expect that the space too be bright whenever and wherever we look at it.



https://en.wikipedia.org/wiki/File:Olber%27s_Paradox_-_All_Points.gif

Explanations of Olbers' paradox

Doppler effect

The sources of light are moving away from us, so that the wavelength of light is shifted towards red. If the shifting was too far, then the light will not be in the range of visible light.

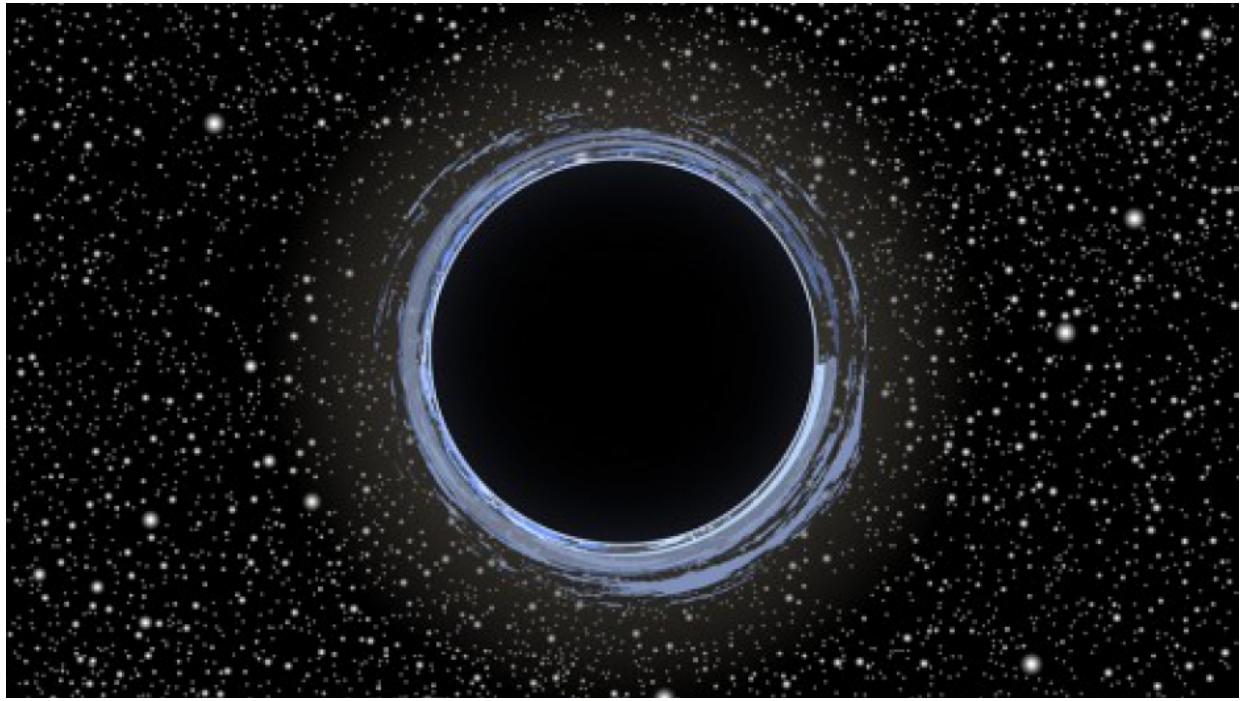
The limited age of the universe

For example, the universe is 15 billion years old, so any light that from the source at more than 15 billion light years away from us will not have enough time to reach us.

Do you remember the adventure of light

Light is not invincible in the space.

There are monsters named black holes which can catch light and imprison it.



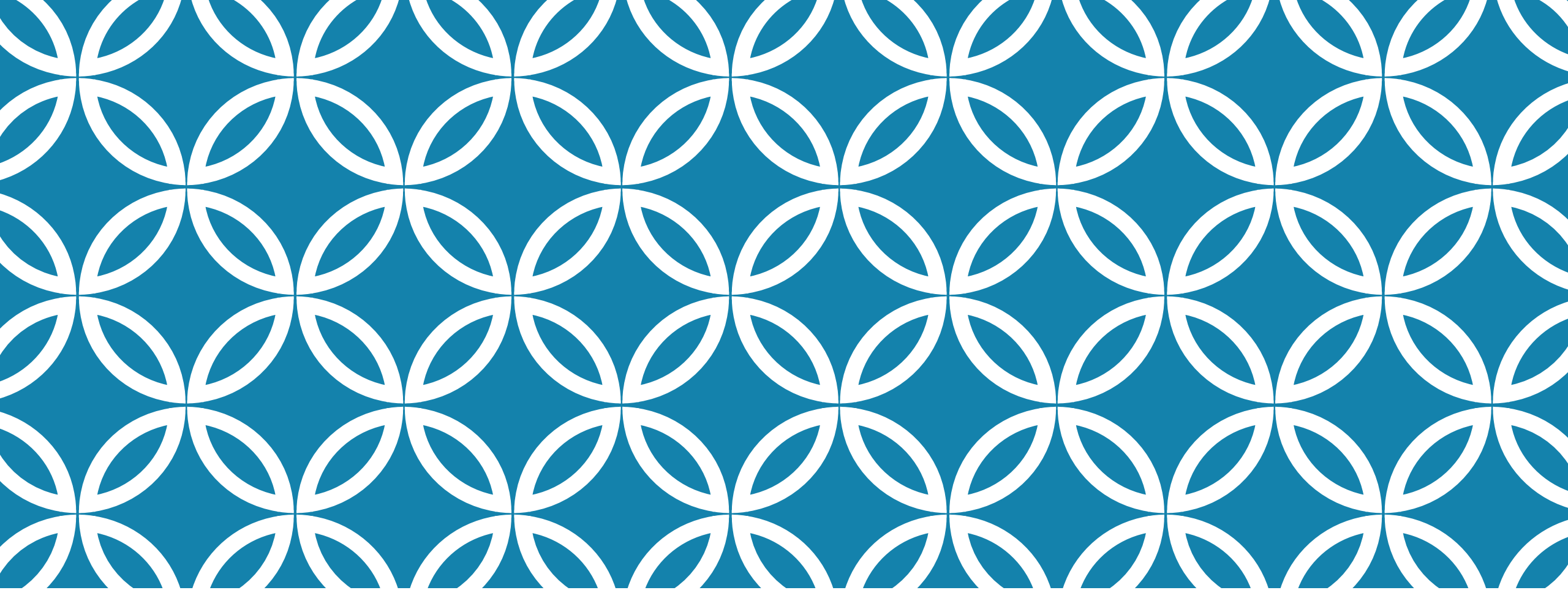
http://www.shutterstock.com/pic-179927561/stock-vector-black-hole-vector.html?src=Ml_Ha1UjuN63ytshKDApeQ-1-20

Due to the gravity, everything needs a certain speed to escape from a planet. The monsters are so big, even as the fastest thing in the universe, light, cannot reach the escape speed.

https://www.flickr.com/photos/drakpimpscooter/3997421484/in/photostream/

I am really glad that there is no black hole in our solar system!

http://theodysseyonline.com/saint-michaels/smile-face-positive-lessons-lyrics/193906



REFLECTION AND REFRACTION

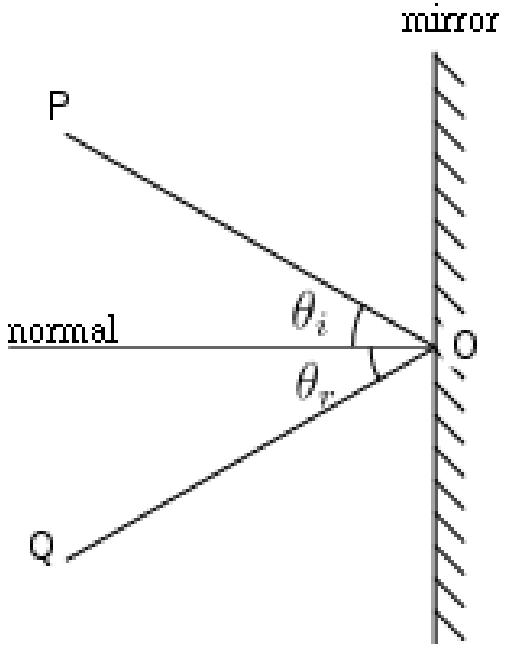
REFLECTION

http://yaunikum.ru/uploads/posts/2011-04/1303542354_1303156281_these_funny_animals_670_26.jpg

Change of direction

Two different media

Return to the original media



https://lh3.googleusercontent.com/OfzQ22u_WXO06xqYFUAXwYBCZAbp8py2q9BjpTkBAdbs9JqkDiJOo2YR13EsN6WWnOIR8Q=s85

THE LAW OF REFLECTION FOR SMOOTH SURFACE

The incident light and the reflected light make the same angle with respect to the reflection surface

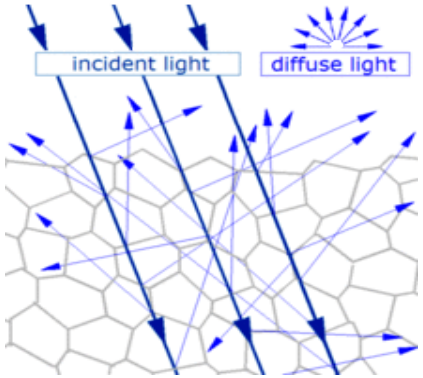
The incident light and the reflected light are mirror image of each other with respect to the normal, the line perpendicular to the surface and bisect the angle formed by the two light paths.

TWO COMMON TYPE OF REFLECTION

Diffusion reflection

Since everything is not perfectly smooth, the reflected light could be in any direction.

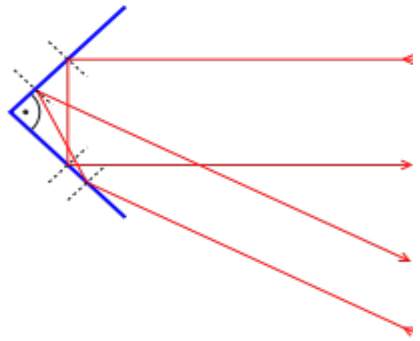
The exact form of reflection depends on the structure of the surface's material.



http://image.dfwsaver.com/upload/c/88/c88ded8e66cabdf0.gif

Multiple reflection

Since we are surrounded by a lot of surface, the light will not only reflect once, it will keep getting reflected until terminates on the path where there is no reflection surface in the way.



https://lh3.googleusercontent.com/yjzi-BQYCut9oJdXWfMDUI7TahxpN8eKuabUaQaU5cpBSDVR_OIBbt1IBM3Mv1HMAKk8To=s98

REFLECTION FROM LESS THAN PERFECT MIRROR

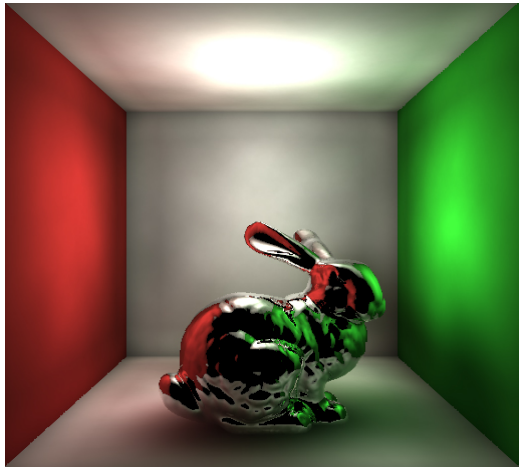
Will all the lights bounce off from the mirror?

Will the energy of light be reduced after the reflection process?

Not all the photon will bounce off from the mirror's surface. Some of photons will be absorbed by the imperfect mirror. This is the main reason that we cannot have infinite reflection between two parallel mirrors.

https://betterbibles.files.wordpress.com/2009/01/image-thumb10.png?w=303&h=447

For lower energy light, every photon that gets reflected from the surface will not lose energy. This is the reason why the reflected light will not change color from the incident light.



http://jihui-shentu.info/wp-content/uploads/2013/12/scene_ref_bunny.jpg

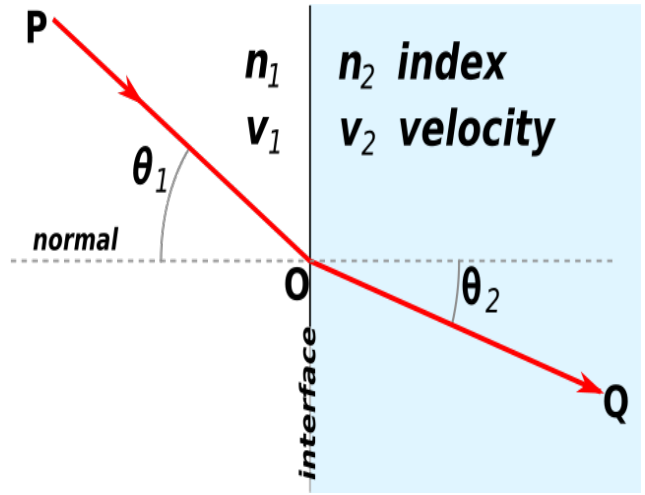
REFRACTION

https://gnagarcia.files.wordpress.com/2009/07/refraction-pencil-all1.jpg

Change of angle

Two media

Go through the other media



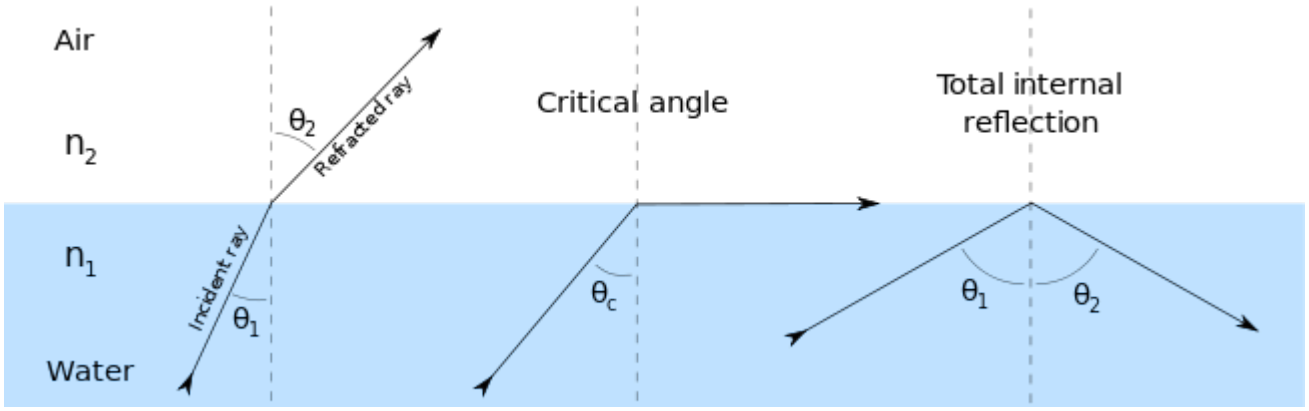
http://40.media.tumblr.com/a56450fcf5d5a000561b0ae6300053d1/tumblr_inline_nype47XMqa1qhyxru_500.png

TWO IMPORTANT FACTS

The change of angle depends on the Transmission medium.

The velocity of light is different in different media, but the frequency of the light remains same.

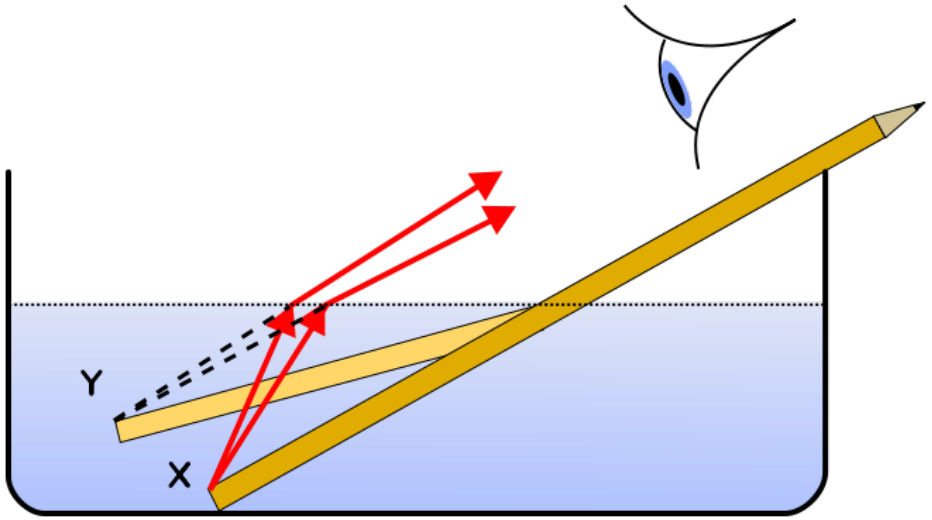
GENERAL WATER-AIR REFRACTION



https://lh3.googleusercontent.com/FAuMYrg2Y9NMqdGZ-XFnv7vNcuV9577as6SUKsMb4JdlHnj0i6uYj2baBVl0pDrMQuXNAhA=s170

WHY DOES THE PENCIL BEND

Our eyes assume that the light comes after refraction has been traveling in a straight line.



http://learn.aiu.edu.au/intranet/Graphics/Editor/marnerosl23/1280px-Pencil_in_a_bowl_of_water.svg.png

Imaging Principle

sciart.eu/sites/default/files/styles/article/public/field/theaser/2548.2095.elszamolni-egyig.jpg?itok=aA_fpv0Q

Why can we see things?

Can you read a book If it were

- In a very dark room
- Very far away from you
- In a turbid river
- Under very bright light

thercnmblog.blogspot.com/2014/09/darkness.html

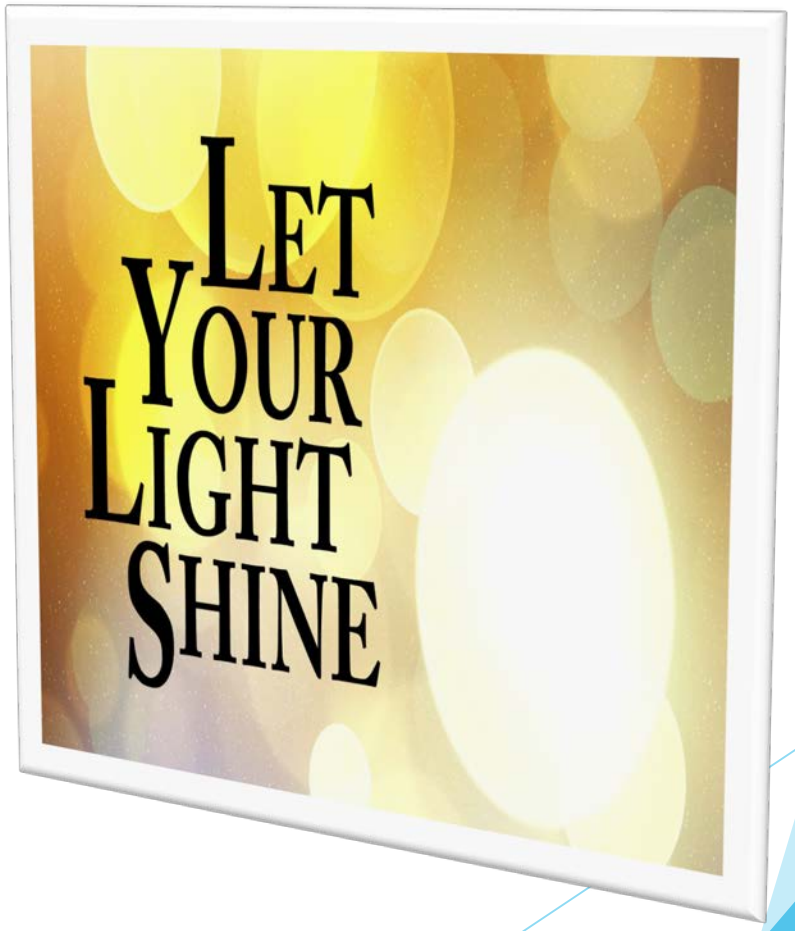
lostcoastlinesdm.wordpress.com/2011/05/18/things-i-like-okkervil-river-part-2

quizlet.com/11935664/8th-grade-science-eog-vocab-flash-cards

www.clipartof.com/gallery/clipart/solar_flare.html

We need light to shine into our eyes

- We can see sun because…
- We can see moon because…
- We cannot read a book in dark room because…
- We cannot read a book from very far because…
- We cannot read a book in a turbid river because..
- We cannot read a book under very bright light because…?



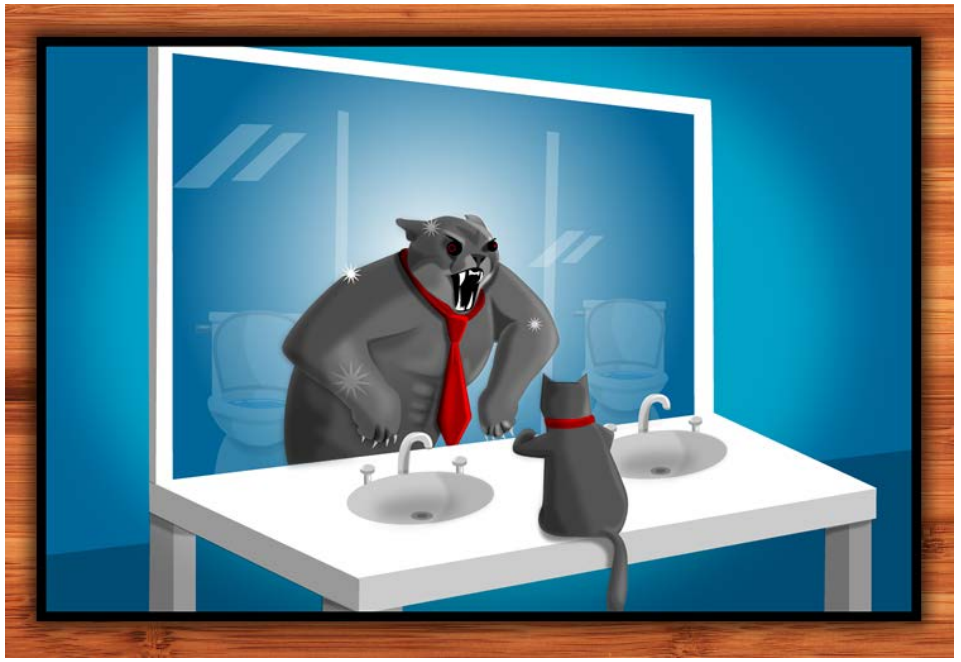
imgur.com/gallery/Z1nxfhX

Light is our friend!

Close friend!

We can even use a mirror!

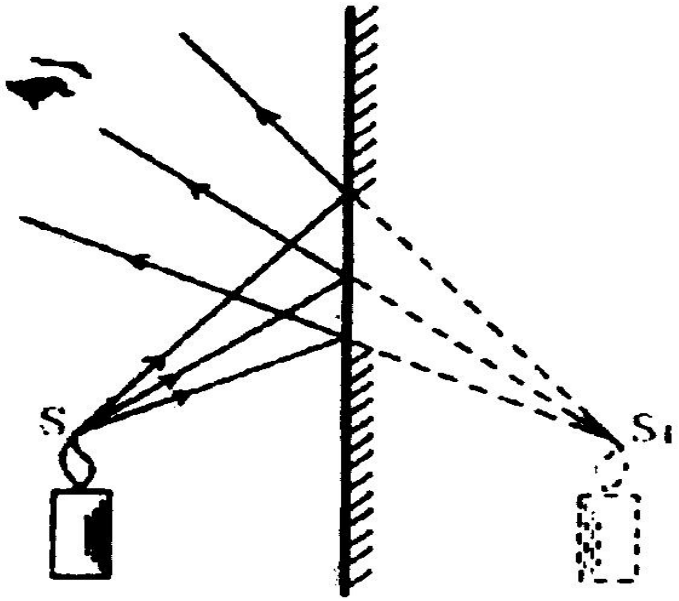
We can even see that thing in the mirror called an image.



puppiesandwordshavepower.files.wordpress.com/2016/04/mirror.png?w=648

Image of a Plane Mirror

- We know that the light travel in a straight line, because of this we can see a **virtual image.**



vir·tu·al im·age

noun OPTICS

an optical image formed from the apparent divergence of light rays from a point, as opposed to an image formed from their actual divergence.

Translations, word origin, and more definitions

quote from google

res.tongyi.com/resources/article/student/junior/2011/0120/wuli/01.files/image004.jpg

Mirrors are an example of a type of optical lens. Can you name some other optical lens you know or anything using optical lens

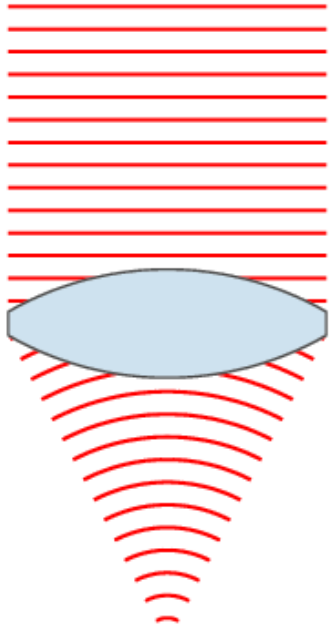
Finally, Today We are learning…

- Convex lens
- Concave lens

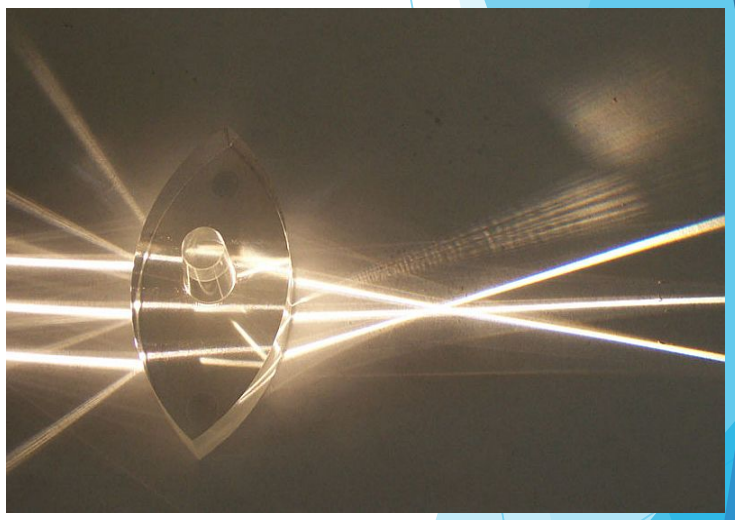
Convex lens

What we see through convex lens is based on:

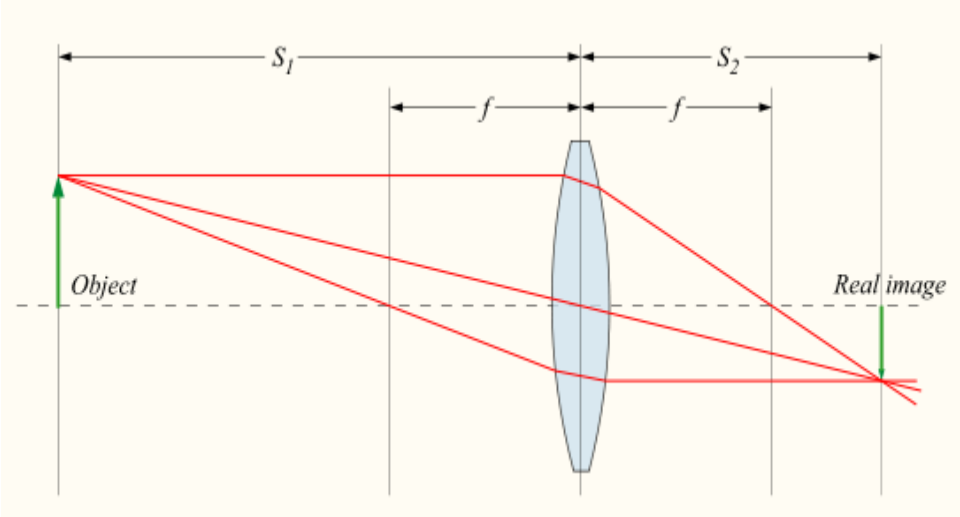
- Focal length
- Object distance



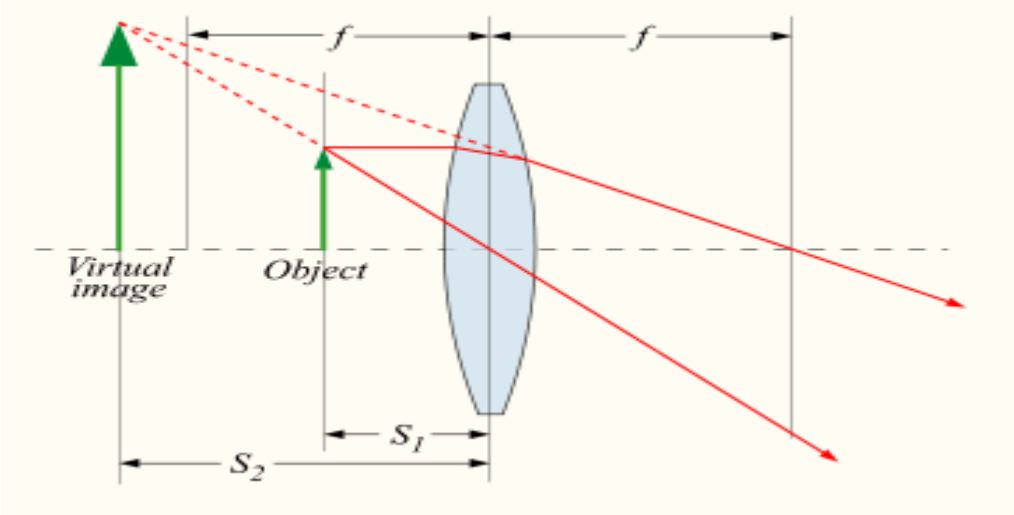
upload.wikimedia.org/wikipedia/commons/thumb/archive/c/c7/20071124005323!Lens_and_wavefronts.gif/50px-Lens_and_wavefronts.gif



http://psychology.wikia.com/wiki/Lens_(optics)



upload.wikimedia.org/wikipedia/commons/thumb/7/71/Lens3.svg/1280px-Lens3.svg.png



https://minireference.com/_media/physics/optics-magnifying-glass.png?w=300

Properties of Convex lens

- $\frac{1}{s_1} + \frac{1}{s_2} = \frac{1}{f}$
- So if we move the object, we will get different images.
- The type of images created can be real or virtual, upside-down or upright, magnified or shrunk.

Examples of convex lens

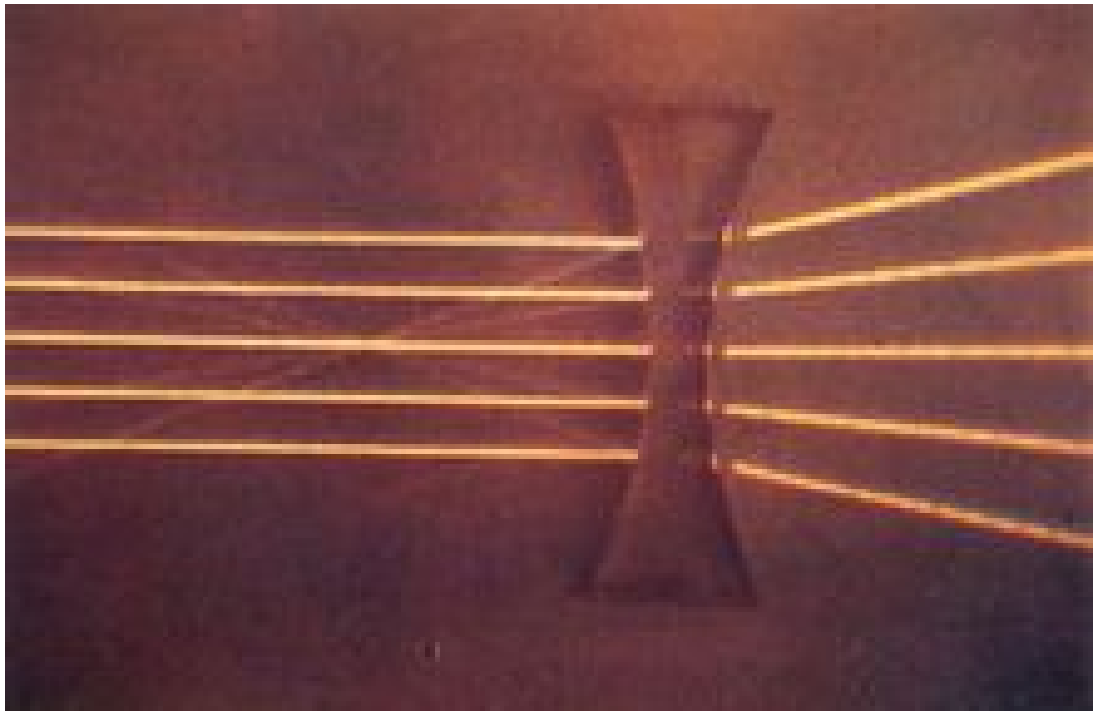
Eye and retina

- What we could see directly must form a real image on retina. But, why don’t we see it upside-down?

Magnifier glass

- How should we choose the focal length of convex lens?

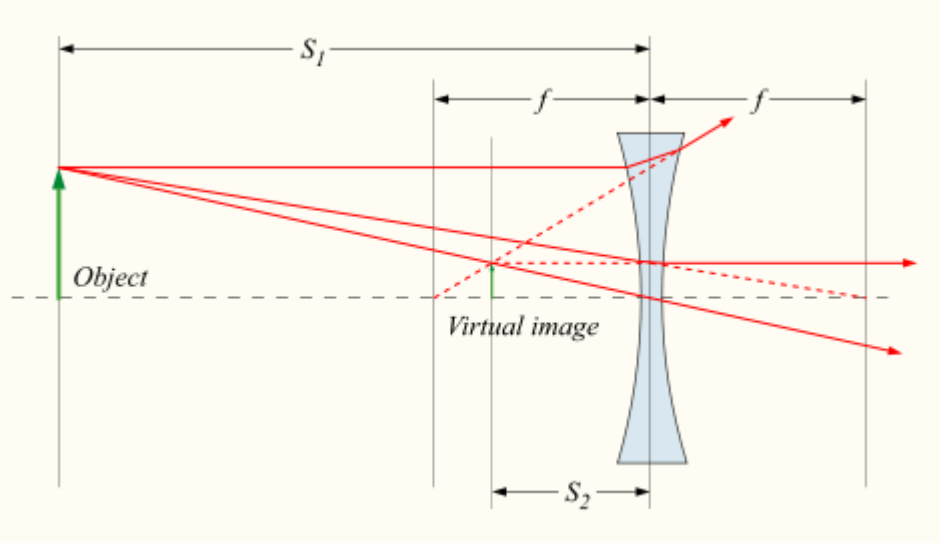
Concave lens



ndb.ndcnc.gov.cn/zxchu/c2wl1/links/links/7/Links/index.htm

Property : $\frac{1}{s_1} + \frac{1}{s_2} = \frac{1}{f}$

The formula is same as the one for Convex lens.
Be careful about the signs here

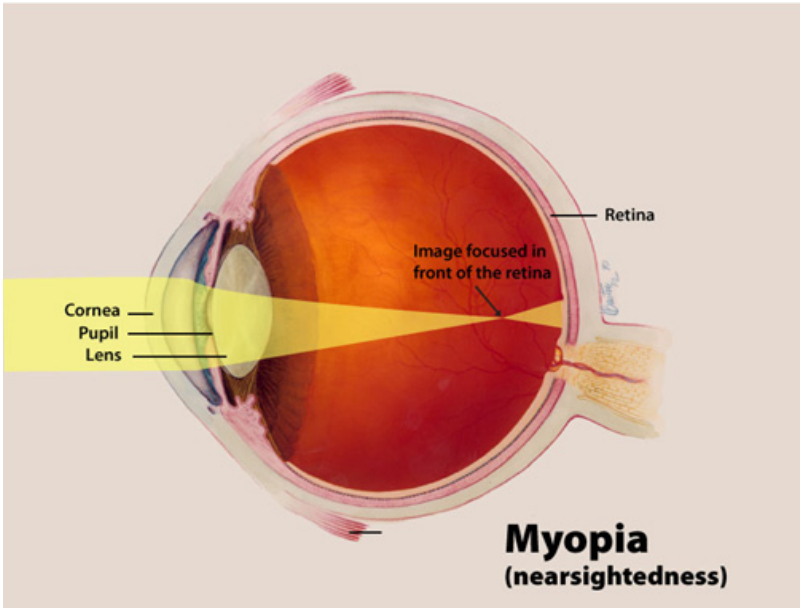


upload.wikimedia.org/wikipedia/commons/thumb/0/03/Lens4.svg/400px-Lens4.svg.png

Our eyes again.

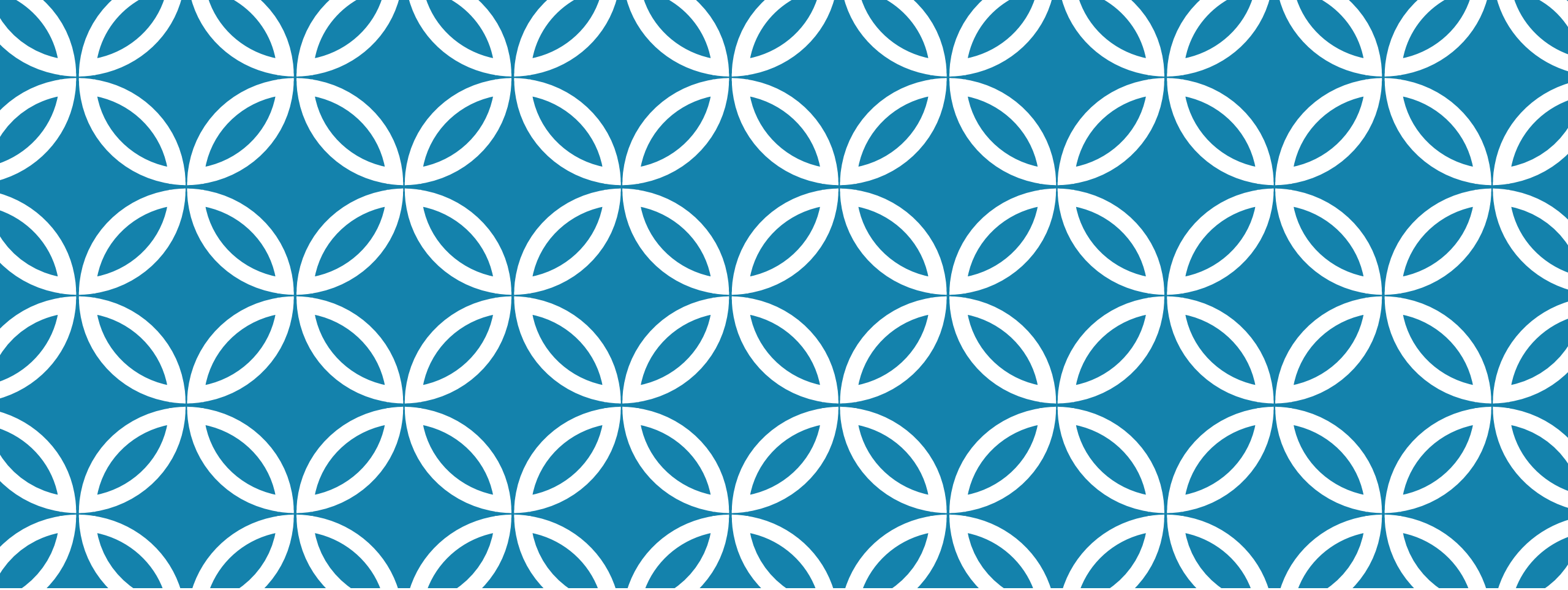
The main use of concave lens in daily life is to correct myopia

Myopia is due to the object's image focused in front of the retina, so that a clear image cannot be formed on the retina



www.kishronakco.com/FileUpload/News/News/Thumbnail/11.jpg

- How can we fix this?



COMBINATION OF LENSES

RECALL

Plane Mirror

Convex lens

Concave Lens

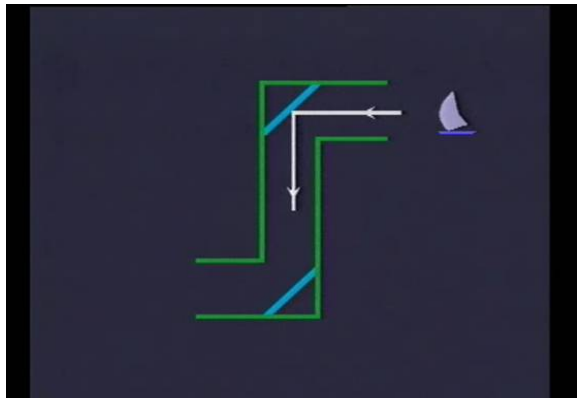
PLANE MIRROR

How does a submarine see ships on the ocean?

How many images does a single plane mirror produce?

How many images does two plane mirrors produce? (attached)

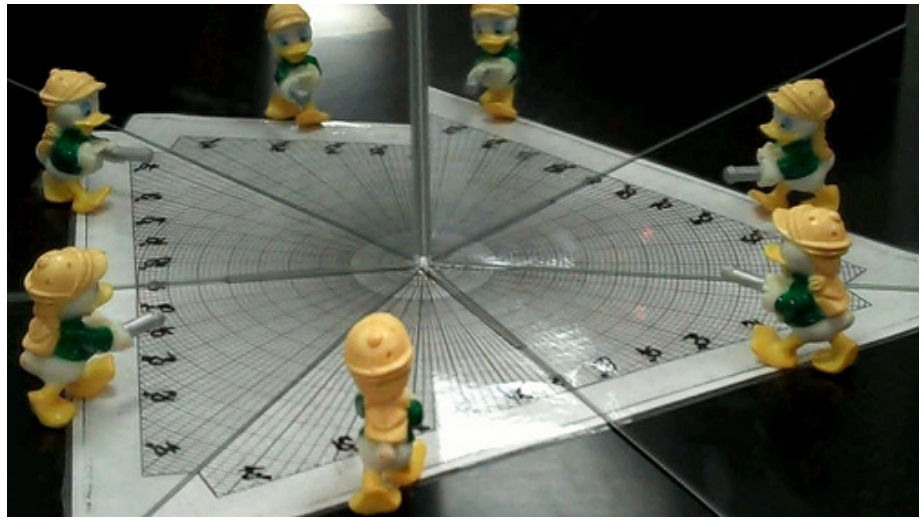
Plan mirror can change the direction of light.



http://cooco.net.cn/techdetail/1679/

A single plane mirror only produces one image.

Two plane mirrors produce at least 3 images.

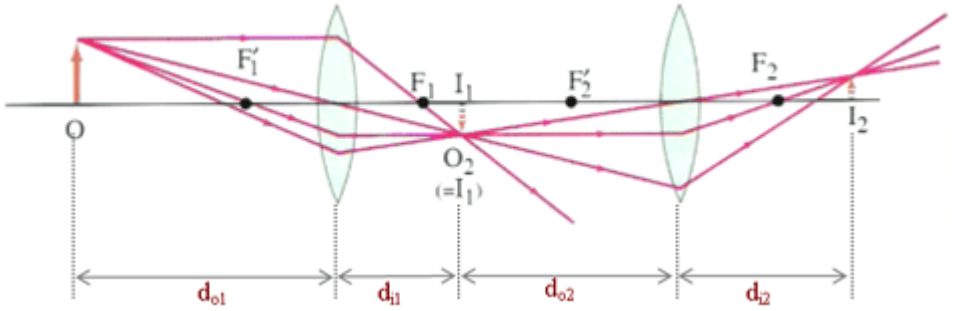


https://www.flickr.com/photos/physicsclassroom

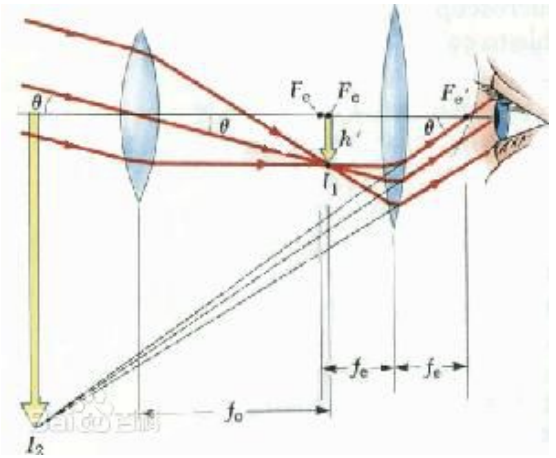
CONVEX LENSES

The combination of Convex lenses is equivalent to a lens of different focal length.

This could be used to make a magnified image of an object. The device with this setup is called microscope.



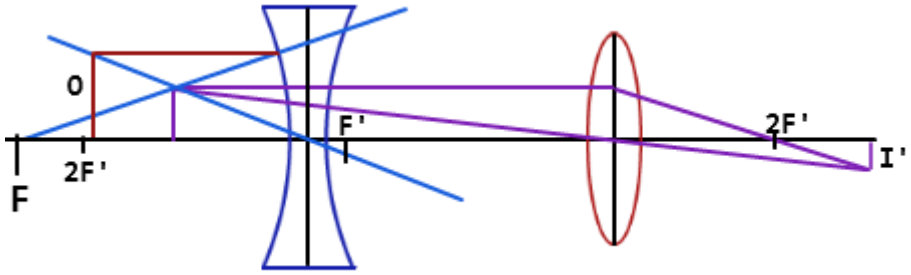
www.livephysics.com/problems-and-answers/optics/lens-system-image-distance-magnification



http://blog.sina.com.cn/s/blog_a7f6f45501018gkf.html

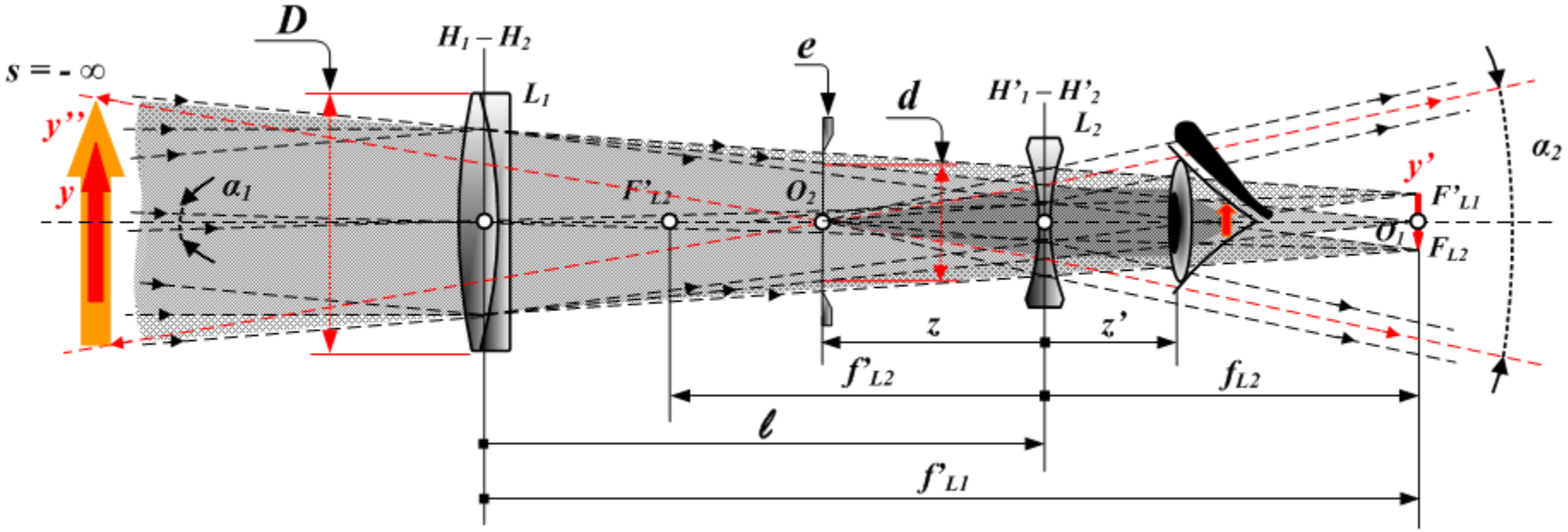
CONVEX LENS AND CONCAVE LENS

This combination is generally used to view object at far distance, called telescope.



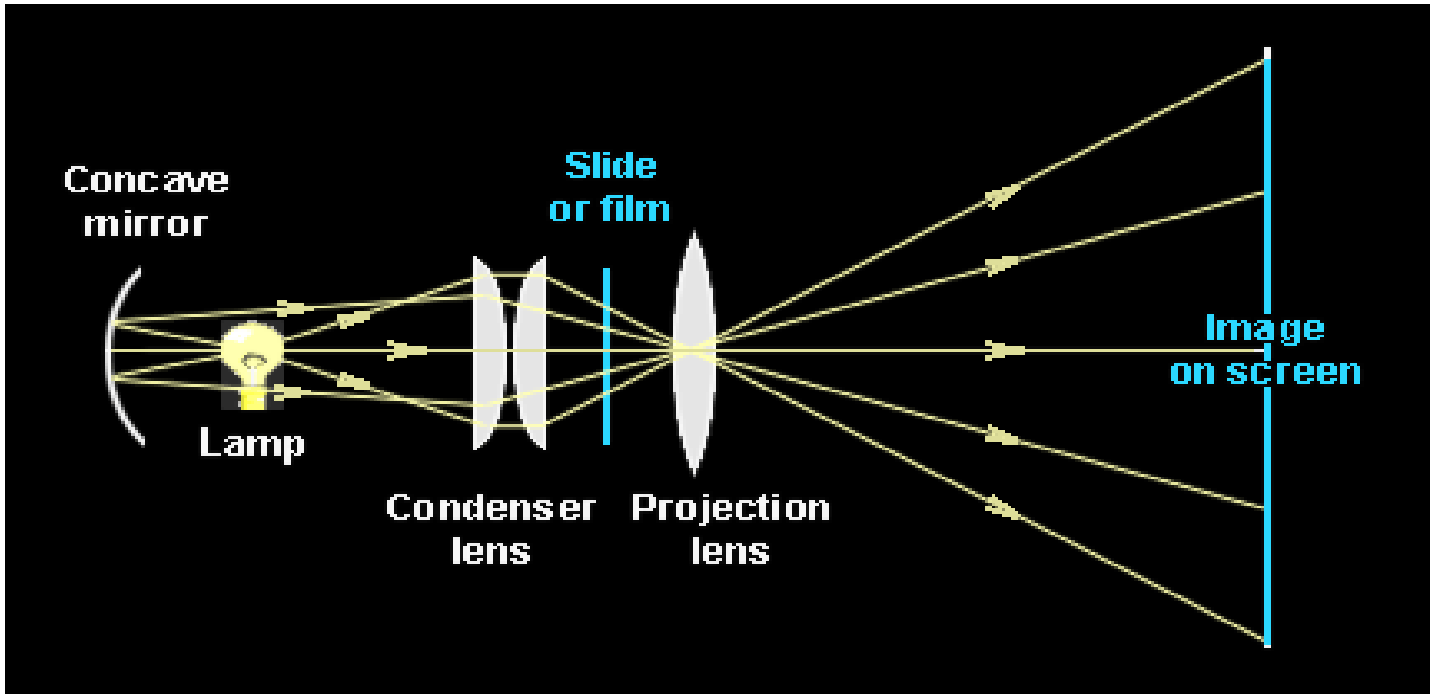
physics.tutorvista.com/light/concave-lens.html

GALILEO'S TELESCOPE



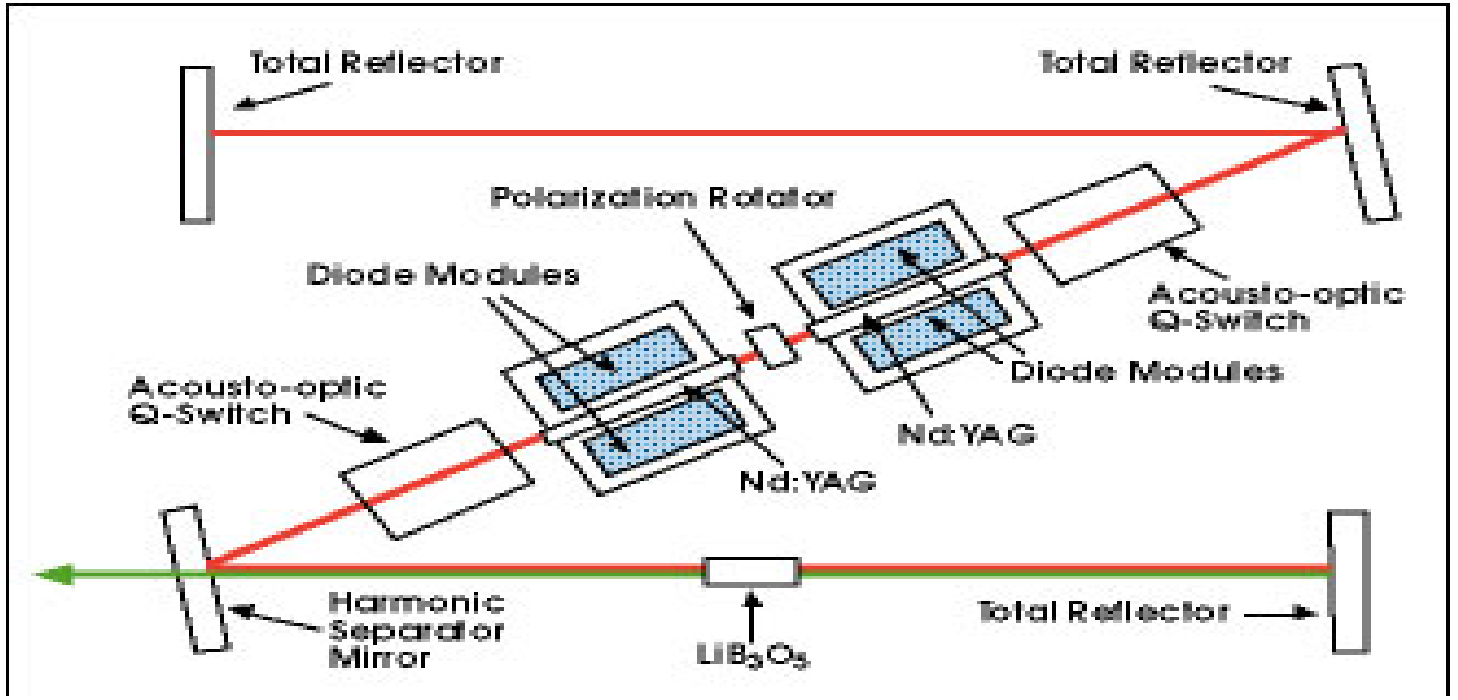
phycafe-blog.tumblr.com/post/21591427720/quantumaniac-galilean-telescope-in-1609

PROJECTOR



www.physchem.co.za/OB11-wav/instruments.htm

LASER



www.photonics.com/Article.aspx?AID=11175

Microscope

- Why do we need the microscope
- What does the microscope look like
- How to use a microscope

- 1590 [Year of invention]
- 400/1600 [The usual zooming in fraction]
- 0.0000001 [The limit of observation]

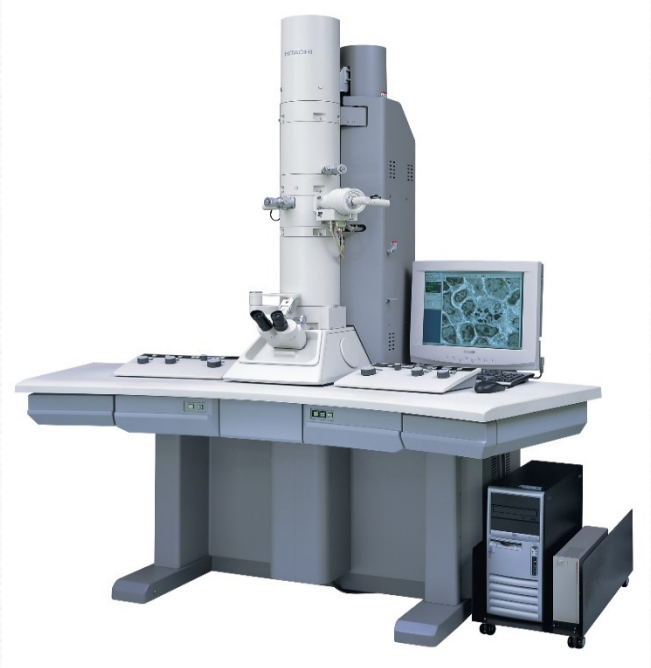
https://media.firebox.com/pic/p5200_column_grid_12.jpg

https://lh3.googleusercontent.com/POtsjVJxolja9yL6nRzV6EKYFVATU1wo-UKbxYswgZDlmQ2E02yOxWkIJuafzz4bX8WU=s155

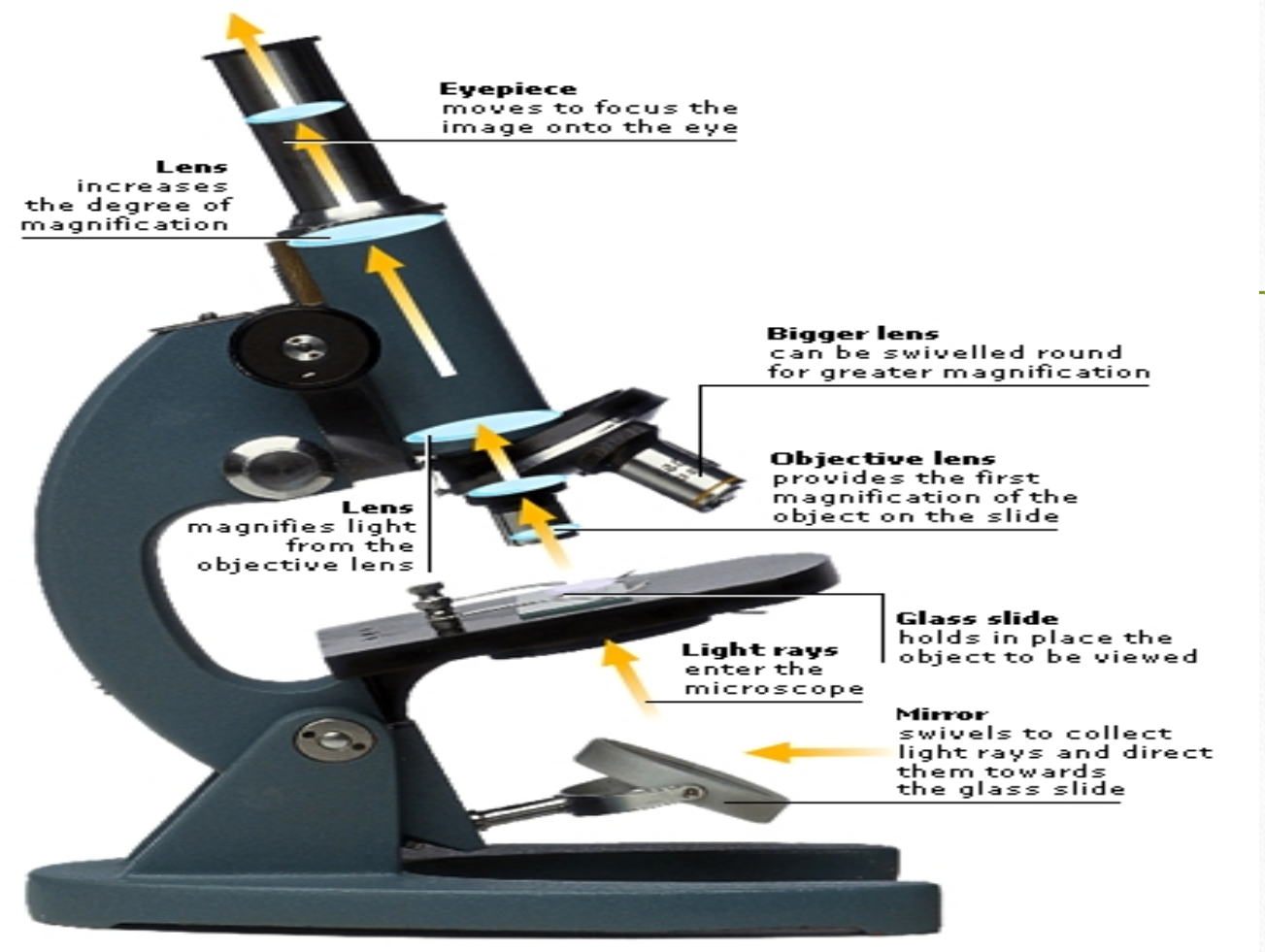
https://lh3.googleusercontent.com/8BRi-N9T4IaM2FnZL6ZIPNkFeZMi14-s2THbsbF85HOg_iwwSJyvKgeOilPhKOSl2Ytk3g=s96

Two types of microscope

2.bp.blogspot.com/-tEXV4ILG1ek/Tlh9IEK7f2I/AAAAAAAAAAw/HGG21hIqwyg/s364/microscope.jpg



http://uic.igc.gulbenkian.pt/images/microscopy/H-7650.JPG



https://s3.amazonaws.com/classconnection/826/flashcards/10473826/jpg/esci116micros001-1532800E9197A322F94.jpg

Prepare to observe

- Make the objective lens to be parallel with arm.
- Adjust the mirror to make the light the brightest.
- Put the observing specimens onto the glass slide
- Observe through the eyepiece while adjusting the focus of the lens.

http://us.123rf.com/400wm/400/400/denisnata/denisnata1102/denisnata110200023/8873446-female-medical-doctor-using-microscope-in-a-laboratory.jpg

Eye and Resolution

Pixel

- Pixel = picture element
- Normally a single pixel is represented as a square in digital devices
- Higher resolution usually means more pixels per area.
- Every single pixel can be filled by different color
- Every single pixel has to be filled fully

wallpaperscraft.com/download/pixels_pacman_bridge_invasion_104316/3840x2160

Resolution

- Resolution in optical describes the ability of presenting the detail of an image
- Any component of a device can affect the resolution, such as lenses and display components.

Some common number

- 16:9

means the ratio of the height and the width of screen

- 1920X1080p

means how many pixels in total, 1080P usually have 2.1 million pixels in total

Camera

- The total amount of pixels is an important standard of evaluating a camera

iPhone 1 (2megapixels)

http://www.pastemagazine.com/articles/2015/05/the-10-most-important-smartphones-of-all-time.html?a=1

iPhone 4 (5 megapixels)

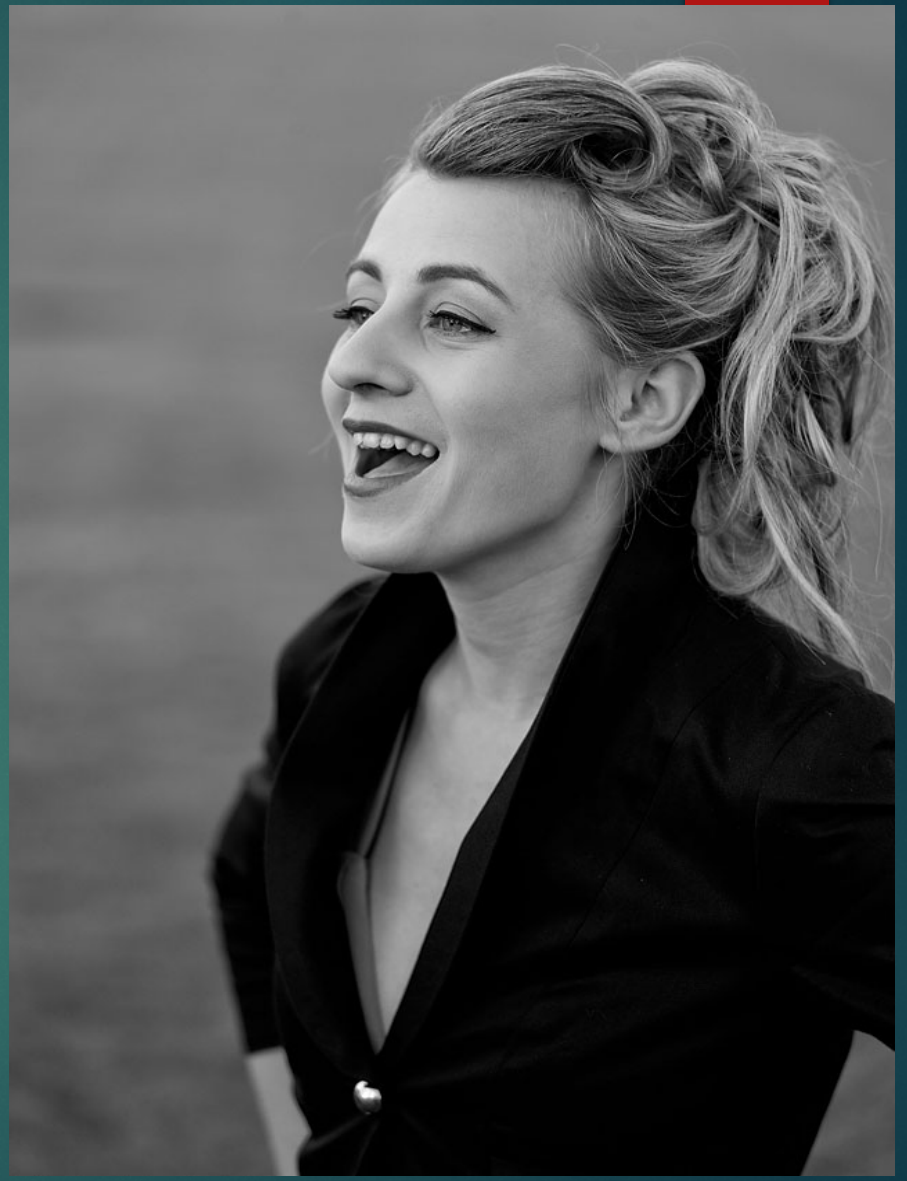
www.phonesplus.com/store/p6/iPhone_4.html

iPhone 6 (8 megapixels)

ohubme.wordpress.com/2016/01/02/mnrv-constructions

http://www.iclarified.com/17578/check-out-how-much-the-iphone-camera-has-improved-over-each-generation

nickstravelbug.com/reviews/iphone-6-review-travel



www.overgaard.dk/the-story-behind-that-picture-0058_gb.html

High resolution

- More squares
- Each square is smaller
- Boundaries are smoother
- Details are clearer

Low resolution

- Less squares
- Each square is bigger
- Boundaries are sharper
- Details are vaguer

How many megapixels does human's eye have

576 megapixels

Eye System

- Eye system is not like a snapshot camera, it is more like a video stream.
- When the light come through the Crystalline lens and reaches Retina, one image is formed at that moment. As the images keep forming, the dynamic information will be sent to our brain and then give us a view of objects.

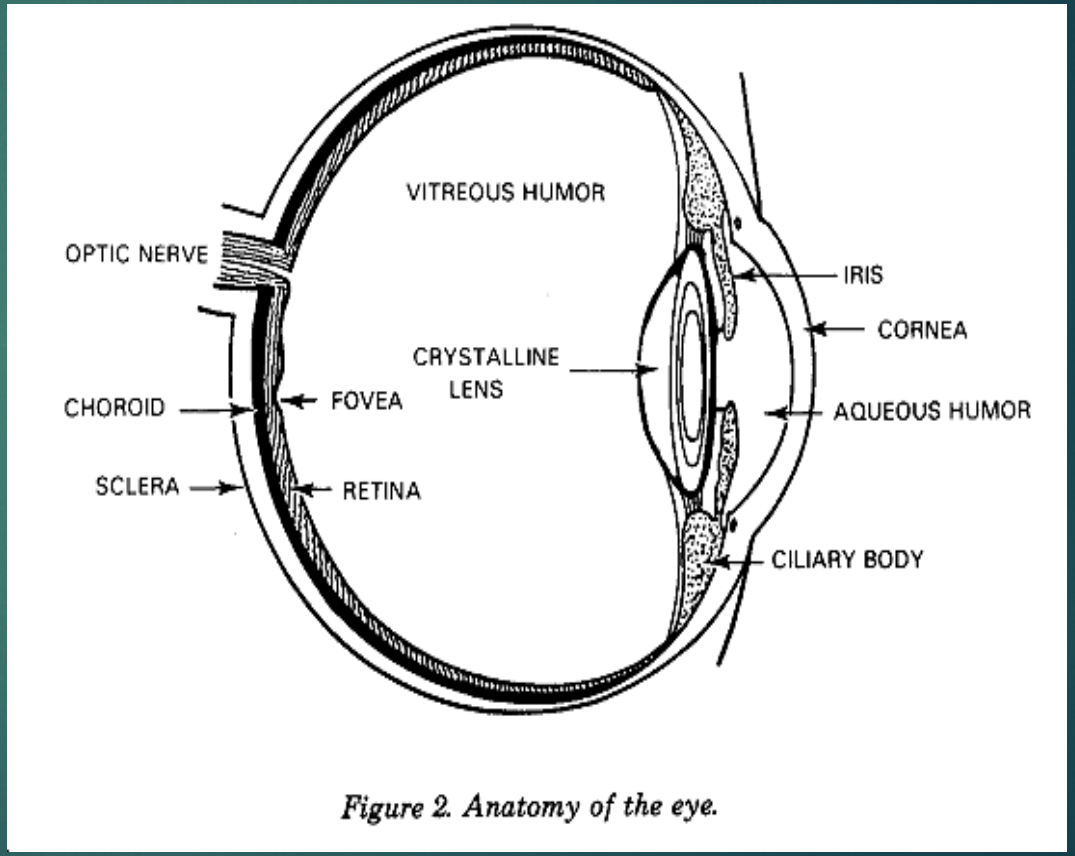


Figure 2. Anatomy of the eye.

www.globalsecurity.org/military/library/policy/army/fm/8-50/INTRO.htm

Capability of the eye

- We can move our eye not slowly and still have a clear figure, this is called angular resolution. When the distance of image on Retina is less than 0.000005m/sec, we will still be able to see clear figure.
- The field of view can be up to 180 degrees. When the eye is stationary, the angle is about 120 degrees.
- Muscle inside eyes can adjust the focus length. The minimum focus length is about 25 cm. When the muscle is totally relax, the focus length can be as far as you want.

What can affect the resolution of eyes

Distance

imgur.com/gallery/Z1nxfhX

Speed

www.dreamstime.com/stock-photography-moving-blue-car-image2600862