Light Test Revision

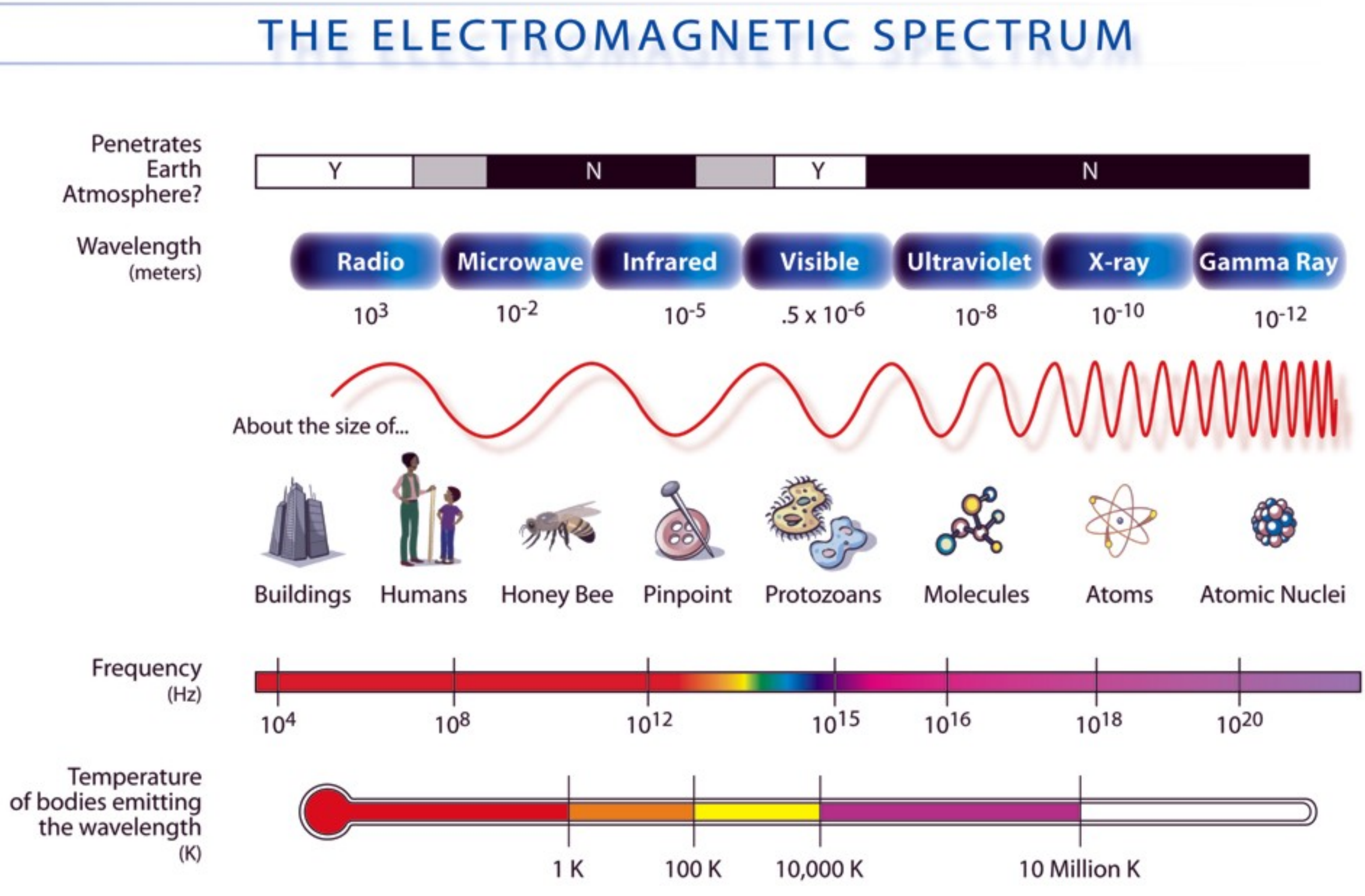
1. **Review basic properties of light** — Properties
2. **Understanding of light behaviour** — Behaviour
3. **The eye** — The eye
4. **Colour** — Colour

Review basic properties of light

- Terminology
- Spectrum of light
- Light travels in straight lines
- It can be refracted and reflected
- Light is an electromagnetic wave

- Light travels in straight ?
- What is the speed of light?

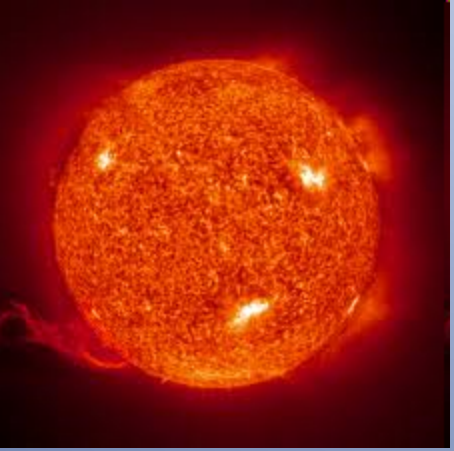
Light is a form of ?


THE ELECTROMAGNETIC SPECTRUM
Penetrates Earth Atmosphere?
Y
N
Y
N
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^3
10^-2
10^-5
.5 x 10^-6
10^-8
10^-10
10^-12
About the size of...
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20
Temperature of bodies emitting the wavelength (K)
1 K
100 K
10,000 K
10 Million K

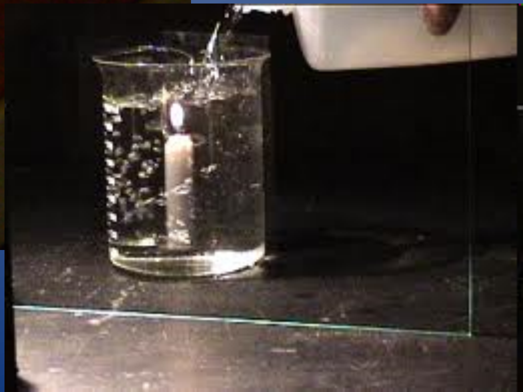
Definitions

- Spectral reflectors: light reflected uniformly
- Diffused reflectors: light is scattered
- Opaque: light is absorbed (blocked)
- Transparent: light passes through
- Translucent: light passes but scattered

Luminous objects



Lit candle in water



Review basic properties of light

Terminology - **Check Your Understanding**

- Electromagnetic spectrum – Place the following in order from largest to smallest wavelength –Microwave, Infrared, Gamma ray, Radio, X-ray, Ultraviolet, Visible
- Sort the following into luminous and non-luminous objects – mirror, firefly, the school principal, electric light, brick, bioluminescent fungi

Understanding of light behaviour

- Reflection
- Refraction (total internal reflection, refractive index)
- Lens behaviour and ray tracing diagrams.
- How glasses can help improve vision
- Advanced: how lenses can be used in cameras, in microscopes and telescopes.

Advanced: how lenses can be used in cameras, in microscopes and telescopes.

- http://www.youtube.com/watch?v=0eZ2o4WNtJU&feature=related
- http://www.youtube.com/watch?v=750YGJ2JXkA&feature=related
- http://www.youtube.com/watch?v=ZCJmSoGN8Zg&feature=related
- http://www.youtube.com/watch?v=ws0Gam6m6bQ&feature=related
- http://www.youtube.com/watch?v=i-hEsFp20pY&feature=relmfu
- http://www.youtube.com/watch?v=qS1FmgPVLqw

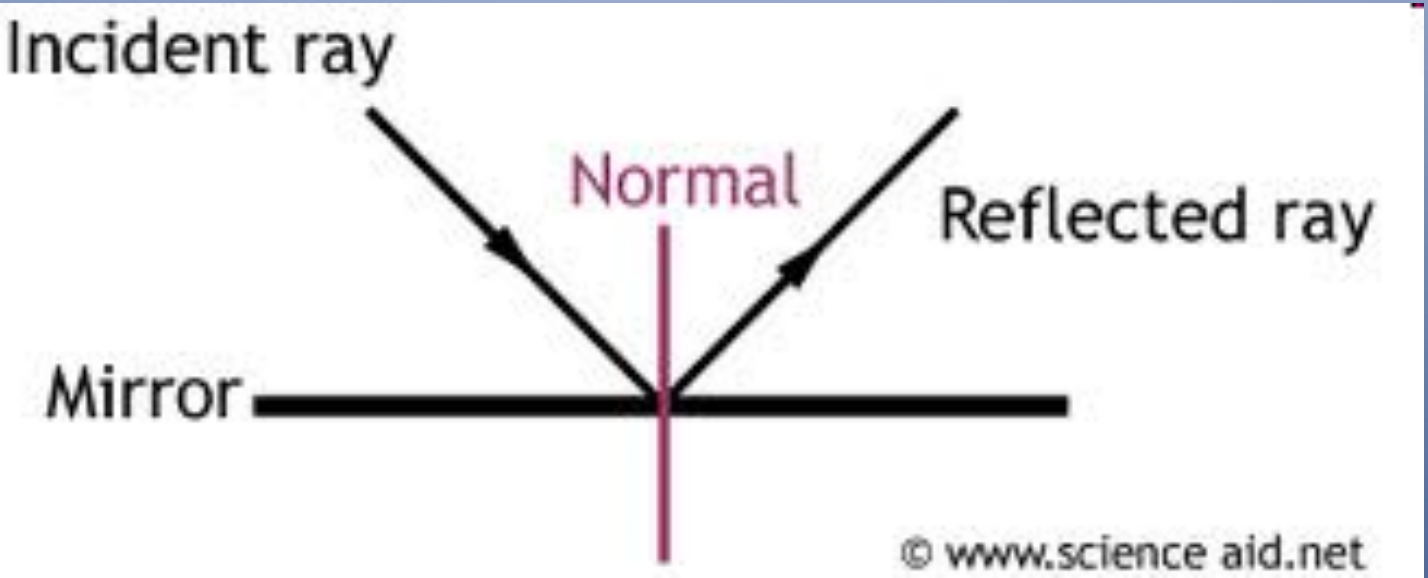
How glasses can help improve vision

- http://www.youtube.com/watch?v=6YxffFmi4Eo&feature=related
- http://www.youtube.com/watch?v=AsKeu4wm3XI&feature=fvwrel

Reflection

- Moon distance
- http://www.lpi.usra.edu/lunar/missions/apollo/apollo_11/experiments/lrr/
- Mirror writing
- http://www.universalleonardo.org/playActivity.php?id=527

Reflection from flat mirror



Experiment 1 How many images?

Aim: to investigate the law of reflection.

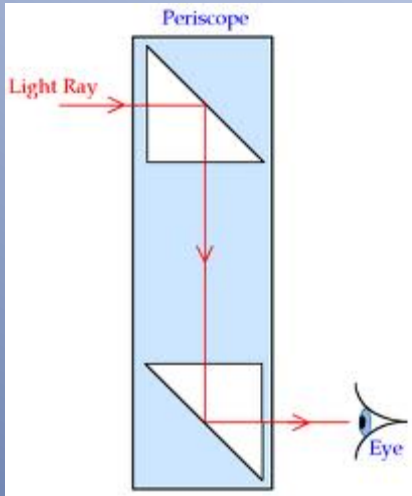
Method:
With 2 mirrors inclined towards each other, record how many images you can see and measure the angle.

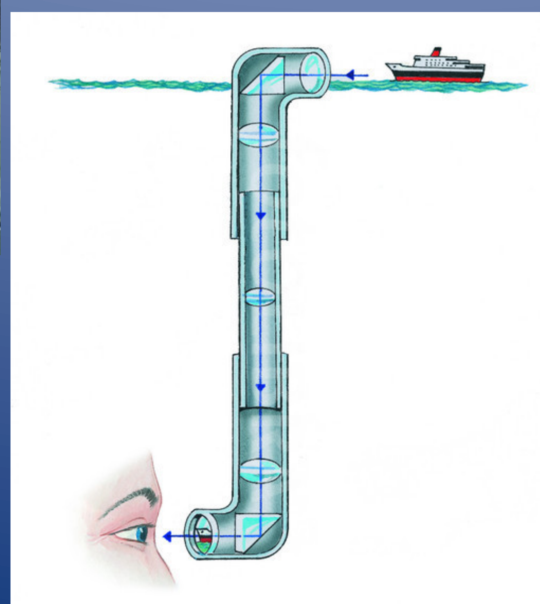
Results:

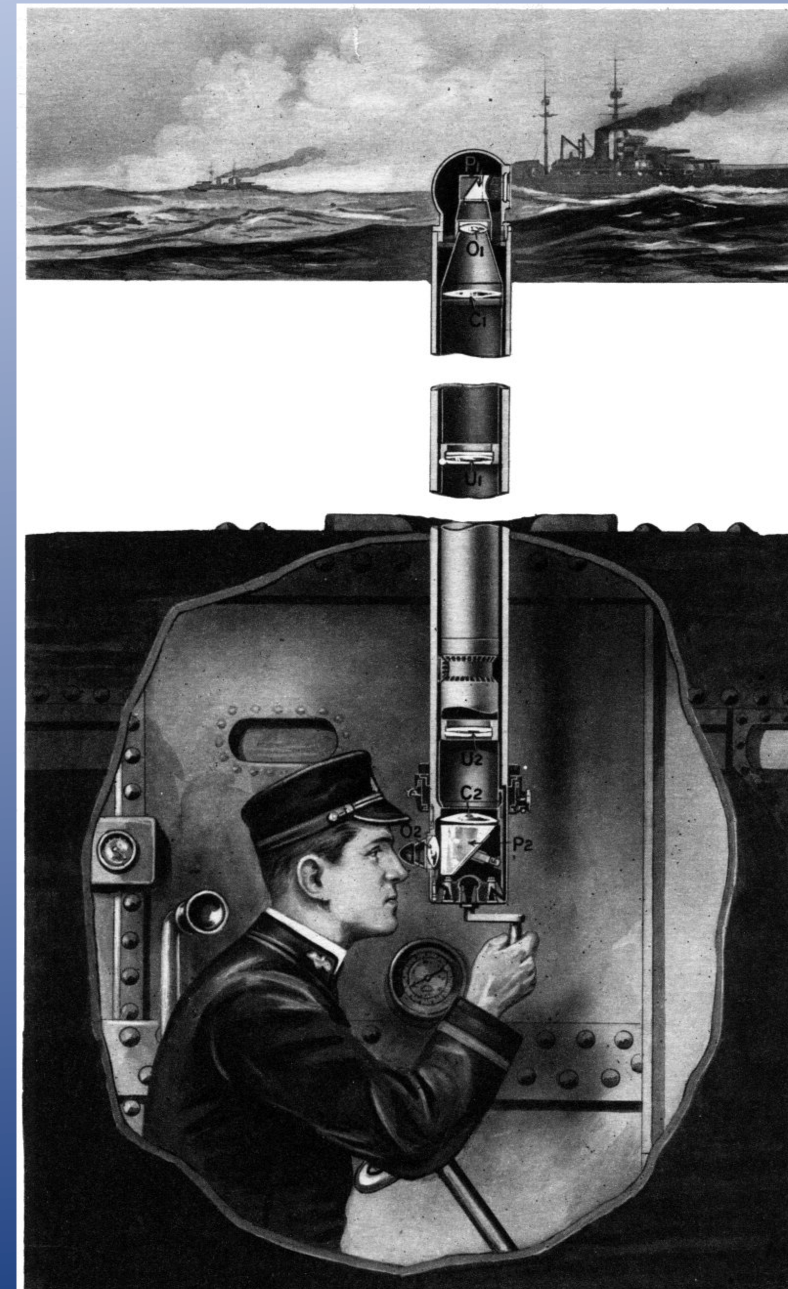
Angle between mirrors	Number of images

Conclusion:
Write a relationship between the numbers of images you could see compared to the angle between the mirrors.

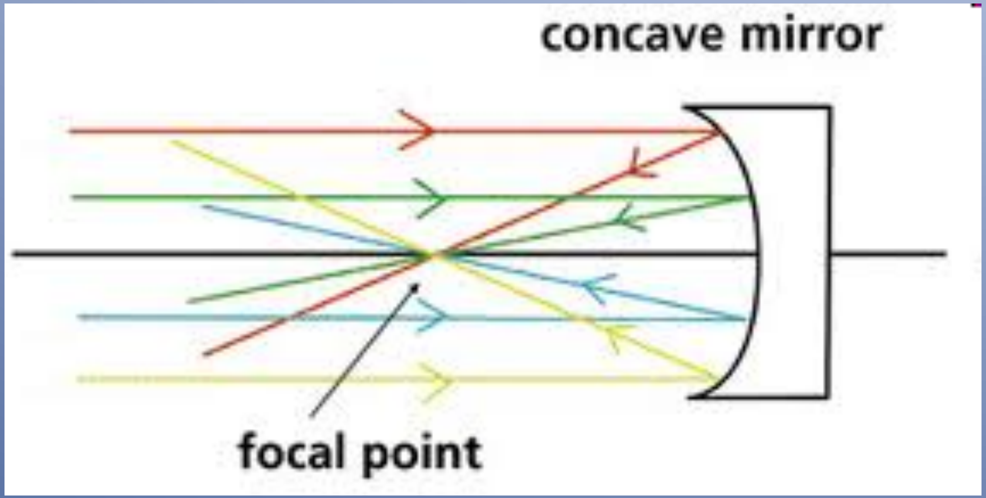
Periscope

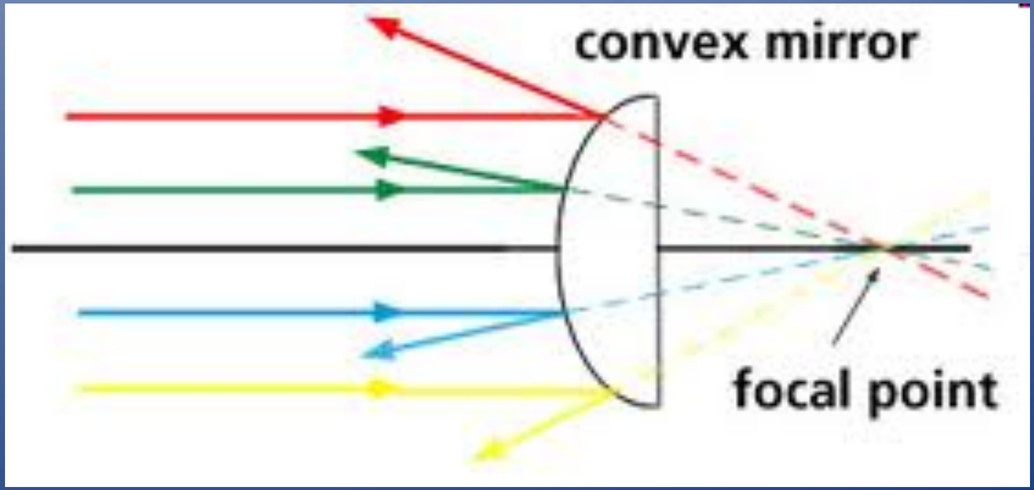






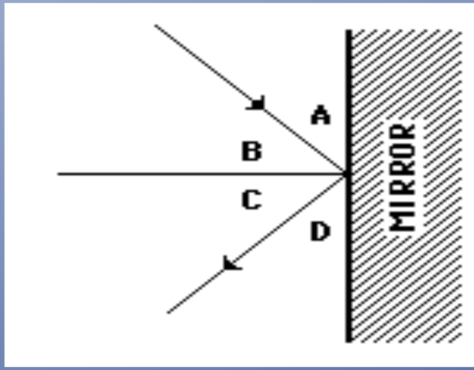
Reflection from curved mirrors



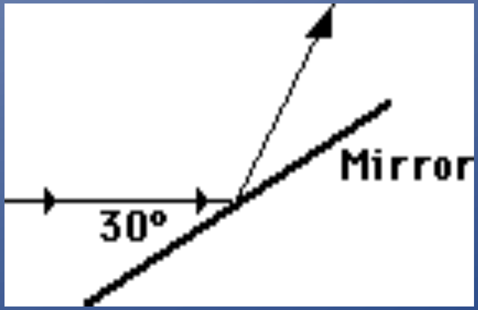


Reflection 1 - **Check Your Understanding**

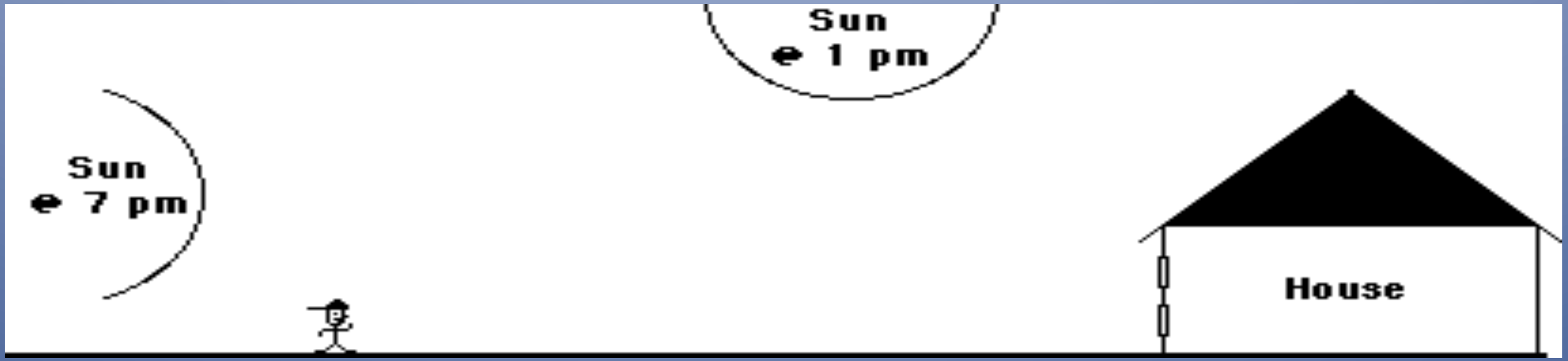
- 1. Consider the diagram at the right. Which one of the angles (A, B, C, or D) is the angle of incidence? _______ Which one of the angles is the angle of reflection? _______



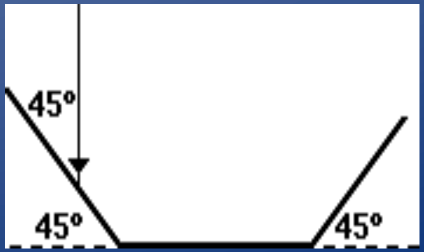
- 2. A ray of light is incident towards a plane mirror at an angle of 30-degrees with the mirror surface. What will be the angle of reflection?



- 3. Perhaps you have observed the image of the sun in the windows of distant buildings near the time that the sun is rising or setting. However, the image of the sun is not seen in the windows of distant building during midday. Use the diagram below to explain, drawing appropriate light rays on the diagram.



- 4. A ray of light is approaching a set of three mirrors as shown in the diagram. The light ray is approaching the first mirror at an angle of 45-degrees with the mirror surface. Trace the path of the light ray as it bounces off the mirror. Continue tracing the ray until it finally exits from the mirror system. How many times will the ray reflect before it finally exits?



- Reflection 1 - Answers
- 1 Angle B is the angle of incidence (angle between the incident ray and the normal). Angle C is the angle of reflection (angle between the reflected ray and the normal).

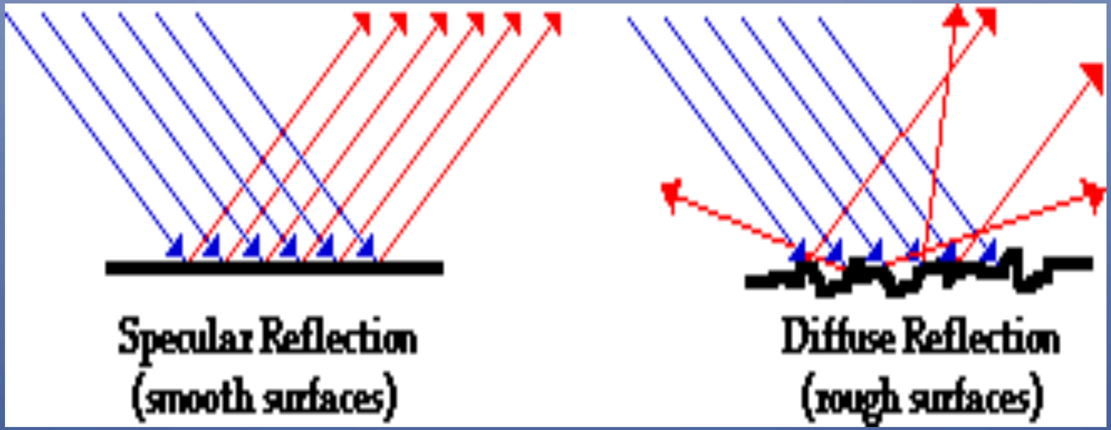
- 2.The angle of reflection is 60 degrees. (Note that the angle of incidence is not 30 degrees; it is 60 degrees since the angle of incidence is measured between the incident ray and the normal.)

- 3. A ray of light drawn from the sun's position at 7 pm to the distant window reflects off the window and travel to the observer's eye. On the other hand, a ray of light drawn from the 1 pm sun position to the window will reflect and travel to the ground, never making it to the distant observer's eye.

- 4. The light reflects twice before it finally exits the system. Draw a normal at the point of incidence to the first mirror; measure the angle of incidence (45 degrees); then draw a reflected ray at 45 degrees from the normal. Repeat the process for the second mirror.

Reflection 2

- Reflection off of smooth surfaces such as mirrors or a calm body of water leads to a type of reflection known as **specular reflection**.
- Reflection off of rough surfaces such as clothing, paper, and the asphalt roadway leads to a type of reflection known as **diffuse reflection**.

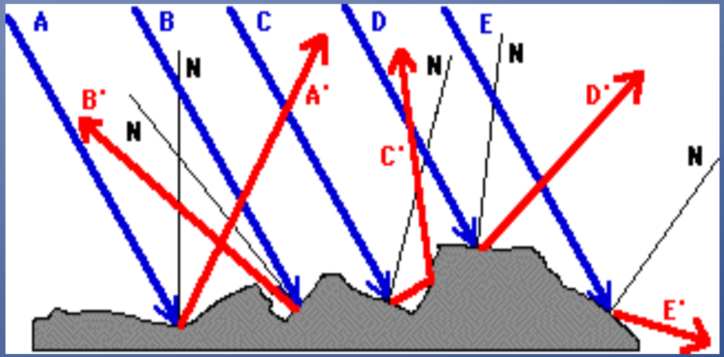


- Whether the surface is microscopically rough or smooth has a tremendous impact upon the subsequent reflection of a beam of light. The diagram depicts two beams of light incident upon a rough and a smooth surface.

- A light beam can be thought of as a bundle of individual light rays which are traveling parallel to each other.
- Each individual light ray of the bundle follows the law of reflection. If the bundle of light rays is incident upon a smooth surface, then the light rays reflect and remain concentrated in a bundle upon leaving the surface.
- On the other hand, if the surface is microscopically rough, the light rays will reflect and diffuse in many different directions.

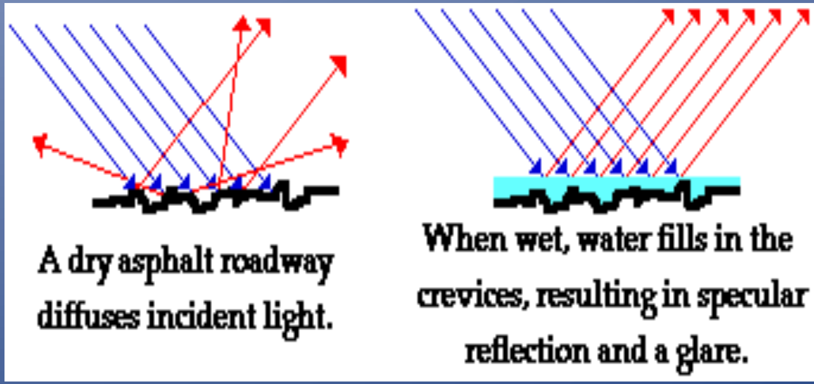
Why Does a Rough Surface Diffuses A Beam of Light?

- For each type of reflection, each individual ray follows the law of reflection. However, the roughness of the material means that each individual ray meets a surface which has a different orientation.
- The normal line at the point of incidence is different for different rays. Subsequently, when the individual rays reflect off the rough surface according to the law of reflection, they scatter in different directions.
- The result is that the rays of light are incident upon the surface in a concentrated bundle and are diffused upon reflection.
- The diagram depicts this principle. Five incident rays (labelled **A**, **B**, **C**, **D**, and **E**) approach a surface. The normal line (approximated) at each point of incidence is shown in black and labelled with an **N**. In each case, the law of reflection is followed, resulting in five reflected rays (labelled **A'**, **B'**, **C'**, **D'**, and **E'**).

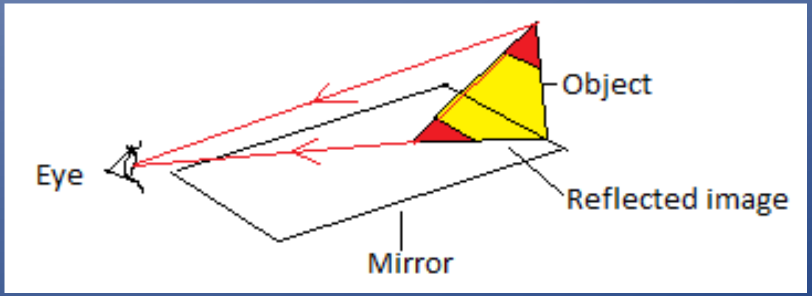


Applications of Specular and Diffuse Reflection

- Most drivers are aware of the fact that driving at night on a wet roadway results in an annoying glare from oncoming headlights.
- The glare is the result of the specular reflection of the beam of light from an oncoming car. Normally a roadway would cause diffuse reflection due to its rough surface. But if the surface is wet, water can fill in the crevices and smooth out the surface.
- Rays of light from the beam of an oncoming car hit this smooth surface, undergo specular reflection and remain concentrated in a beam. The driver perceives an annoying glare caused by this concentrated beam of reflected light.



- The water (if calm) provides for the specular reflection of light from the subject of the photograph.
- Light from the subject can reach the camera lens directly or it can take a longer path in which it reflects off the water before traveling to the lens.
- Since the light reflecting off the water undergoes specular reflection, the incident rays remain concentrated (instead of diffusing). The light is thus able to travel together to the lens of the camera and produce an image (an exact replica) of the subject which is strong enough to perceive in the photograph.



Parabolic reflectors

Check Your Understanding

- 1. If a bundle of parallel incident rays undergoing diffuse reflection follow the law of reflection, then why do they scatter in many different directions after reflecting off a surface?

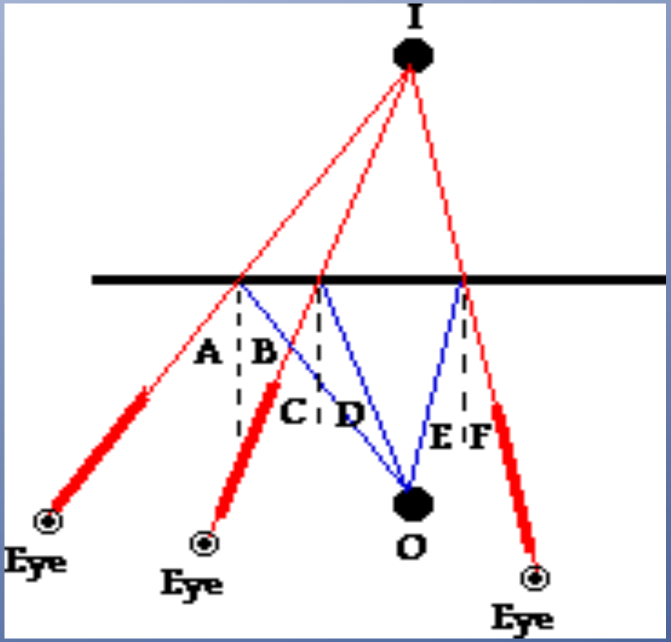
- 2. Perhaps you have observed magazines which have glossy pages. The usual microscopically rough surface of paper has been filled in with a glossy substance to give the pages of the magazine a smooth surface. Do you suppose that it would be easier to read from rough pages or glossy pages? Explain your answer.

- Answers
- Each individual ray strikes a surface which has a different orientation. Since the normal is different for each ray of light, the direction of the reflected ray will also be different.

- It is much easier to read from rough pages which provide for diffuse reflection. Glossy pages result in specular reflection and cause a glare. The reader typically sees an image of the light bulb which illuminates the page. If you think about, most magazines which use glossy pages are usually the type which people spend more time viewing pictures than they do reading articles.

Image Formation in Plane Mirrors

- Each person sees the image due to the reflection of light off the mirror in accordance with the law of reflection.
- When each line of sight is extended backwards, each line will intersect at the same point. This point is the image point of the object.
- Light does not actually pass through the location on the other side of the mirror; it only appears to an observer as though the light is coming from this location.
- Whenever a mirror (whether a plane mirror or otherwise) creates an image that is **virtual**, it will be located behind the mirror where light does not really come from.



Check Your Understanding

- 1. You might have noticed that emergency vehicles such as ambulances are often labelled on the front hood with reversed lettering (e.g., ECNALUBMA). Explain why this is so.

- 2. If Suzie stands 2 metres in front of a plane mirror, how far from the person will her image be located?

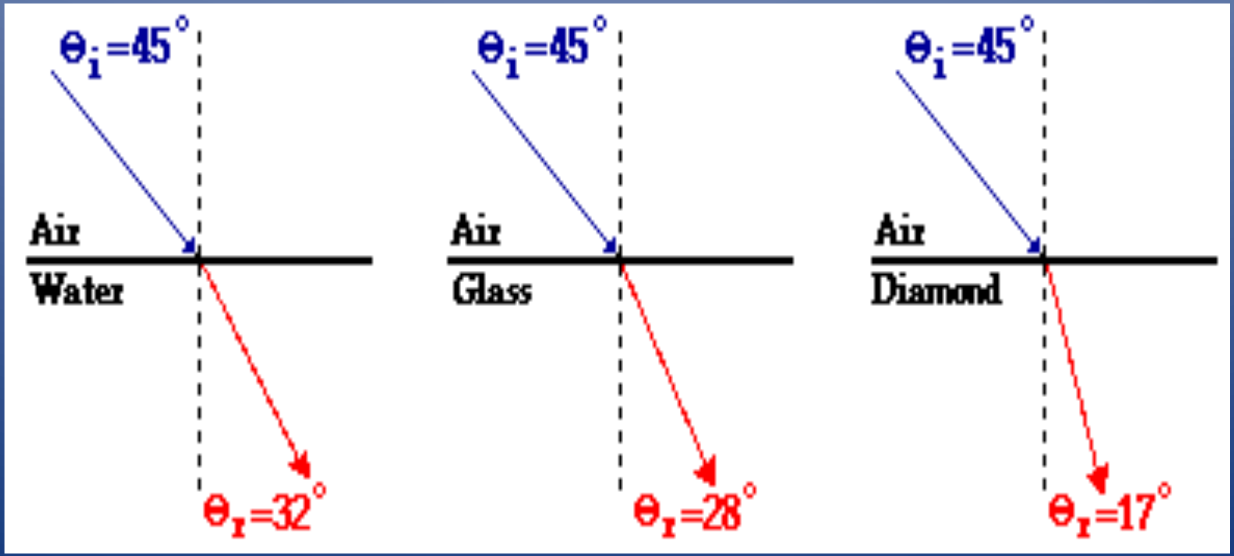
- Most drivers will view the ambulance in their rear-view mirrors. As such, they will be viewing an image of the lettering. Such images appear with left-right reversal and so will be viewed with the proper orientation - AMBULANCE.
- Answer = **4 metres**
- Suzie (the object) is located 2 metres from the mirror. Suzie's image will be located 2 metres behind the mirror. Thus, the distance between Suzie and the image will be 4 metres.

Refraction

- **Refraction** is the bending of the path of a light wave as it passes from one material into another material.
- The refraction occurs at the boundary and is caused by a change in the speed of the light wave upon crossing the boundary.
- The tendency of a ray of light to bend one direction or another is dependent upon whether the light wave speeds up or slows down upon crossing the boundary.

Light Traveling from a Fast to a Slow Medium

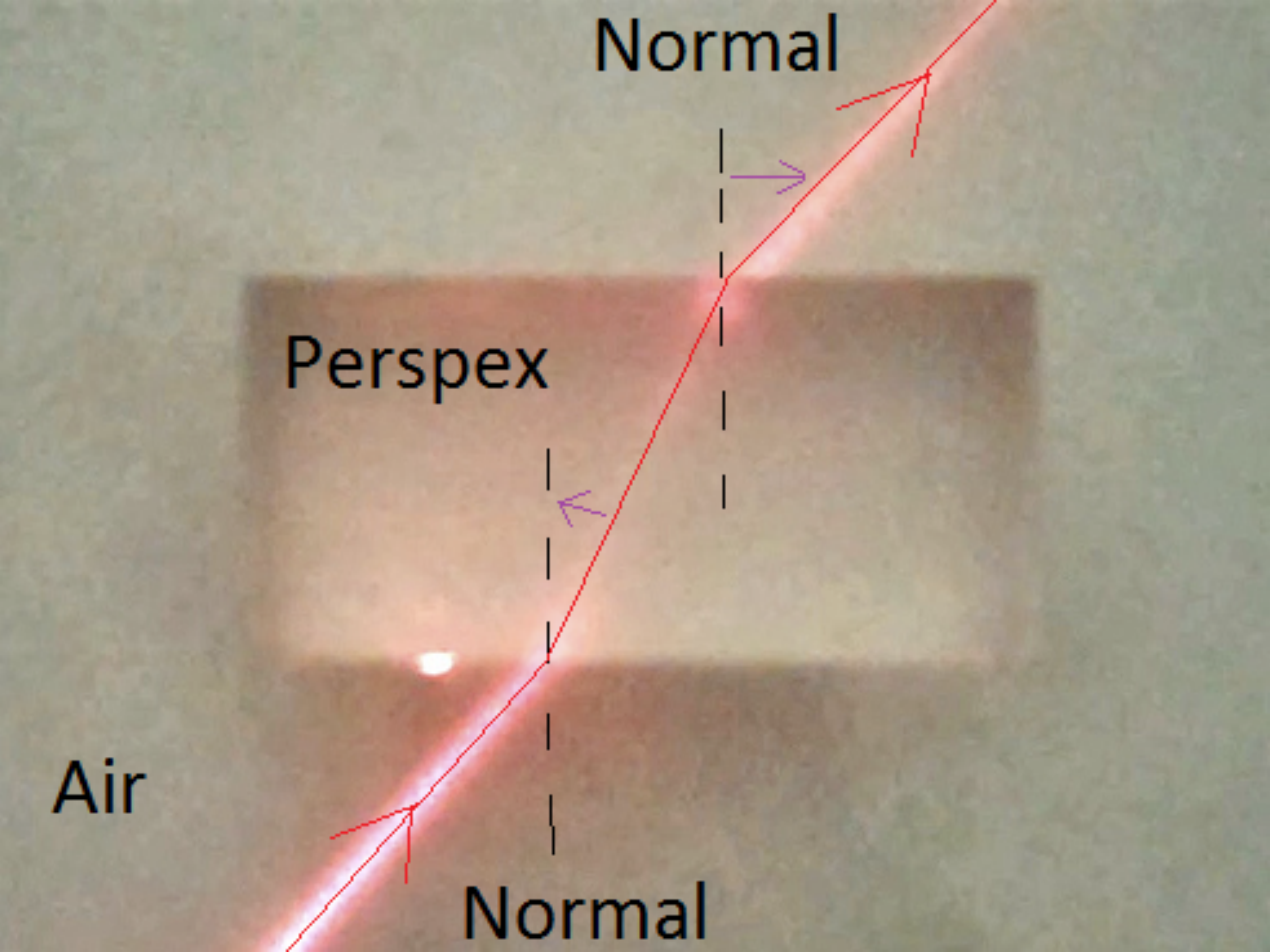
- **FST = Fast to Slow, Towards Normal**
- If a ray of light passes across the boundary from a material in which it travels **f**ast into a material in which travels **s**lower, then the light ray will bend **t**owards the normal line.



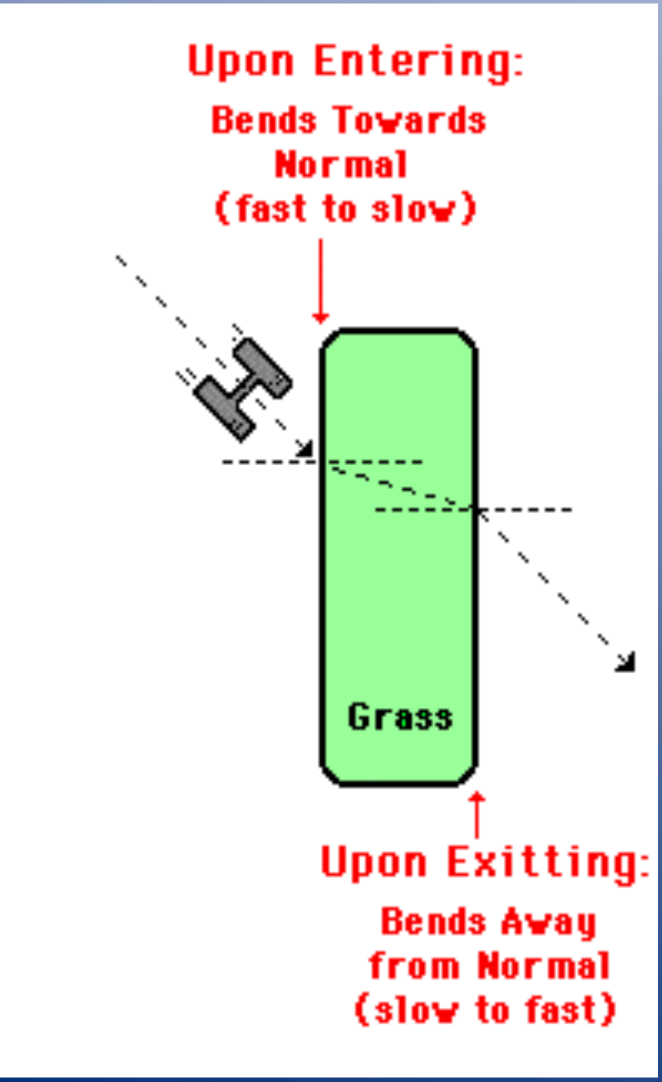
Light Traveling from a Slow to a Fast Medium

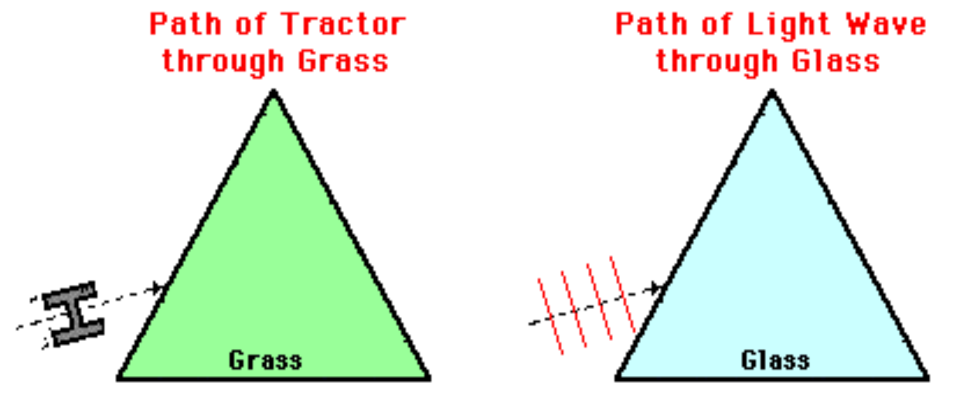
- **SFA = Slow to Fast, Away From Normal**
- If a ray of light passes across the boundary from a material in which it travels **s**low into a material in which travels **f**aster, then the light ray will bend **a**way from the normal line.

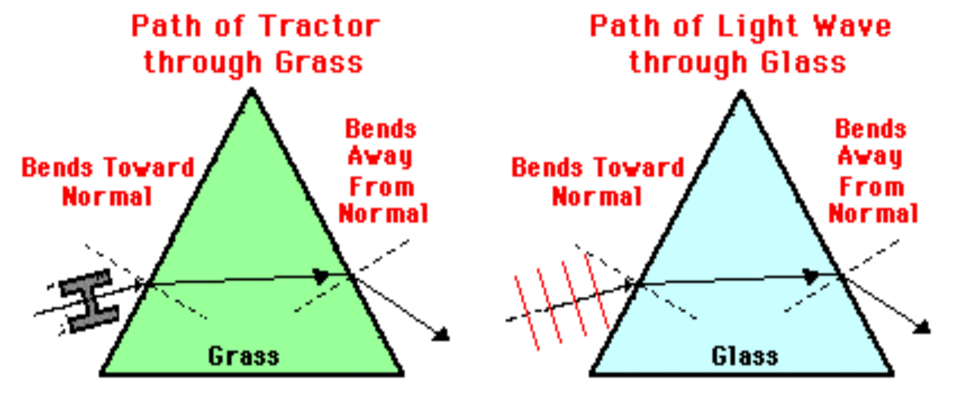
- You can remember FST by **Fantastic Science Teachers** that you have had through the years. And you can remember SFA by **Science Fun Again**.


Normal
Perspex
Air
Normal

Refraction Analogies

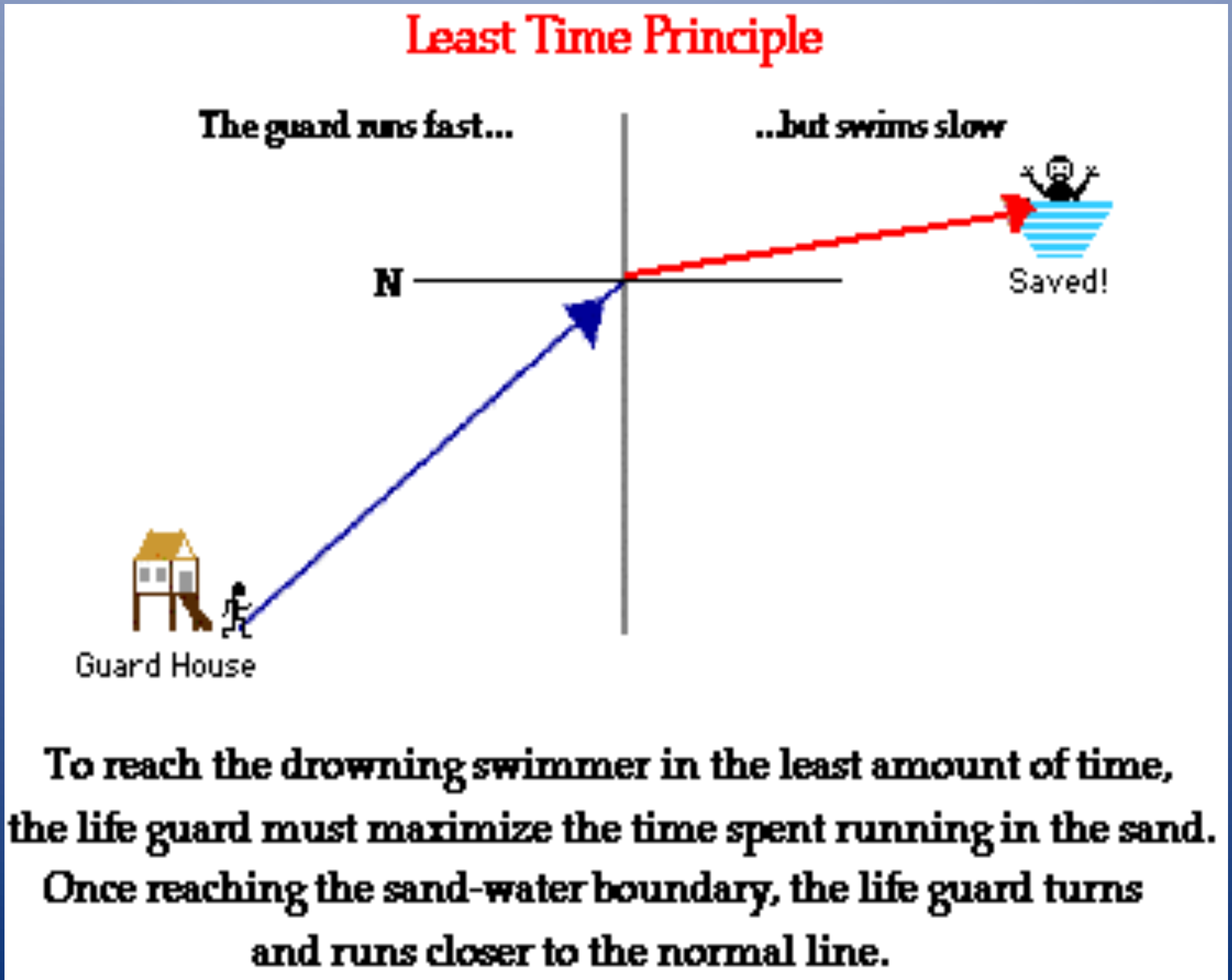






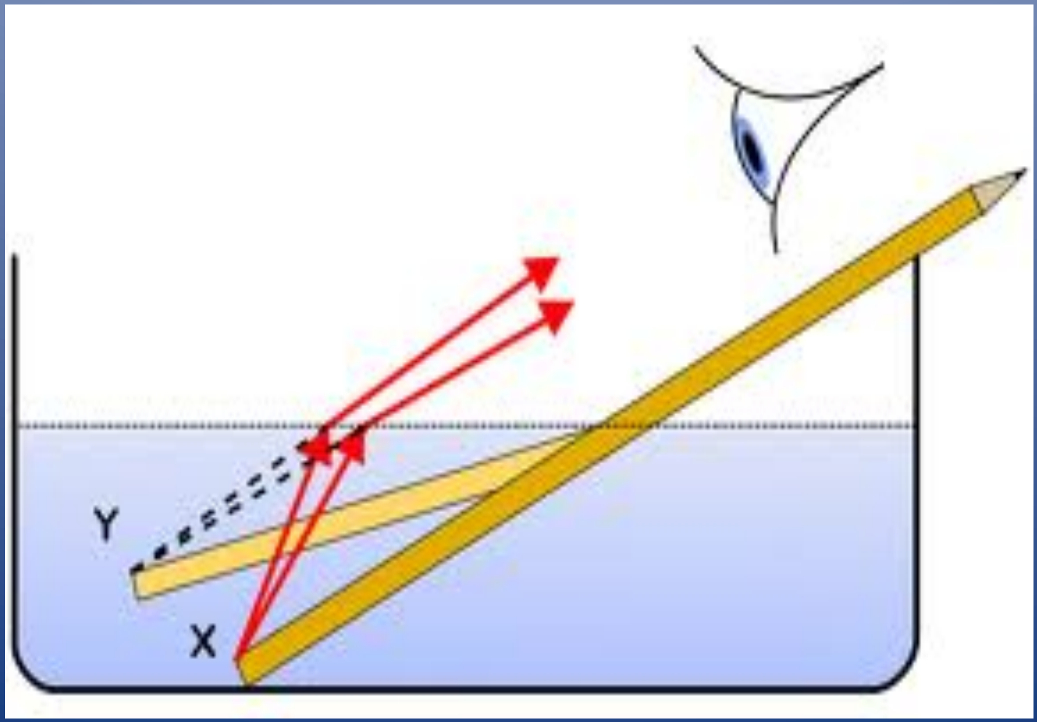
Least Time Principle

- Of all the possible paths that light might take to get from one point to another, it always takes the path that requires the least amount of time.



Why does a pencil appear to bend in water?

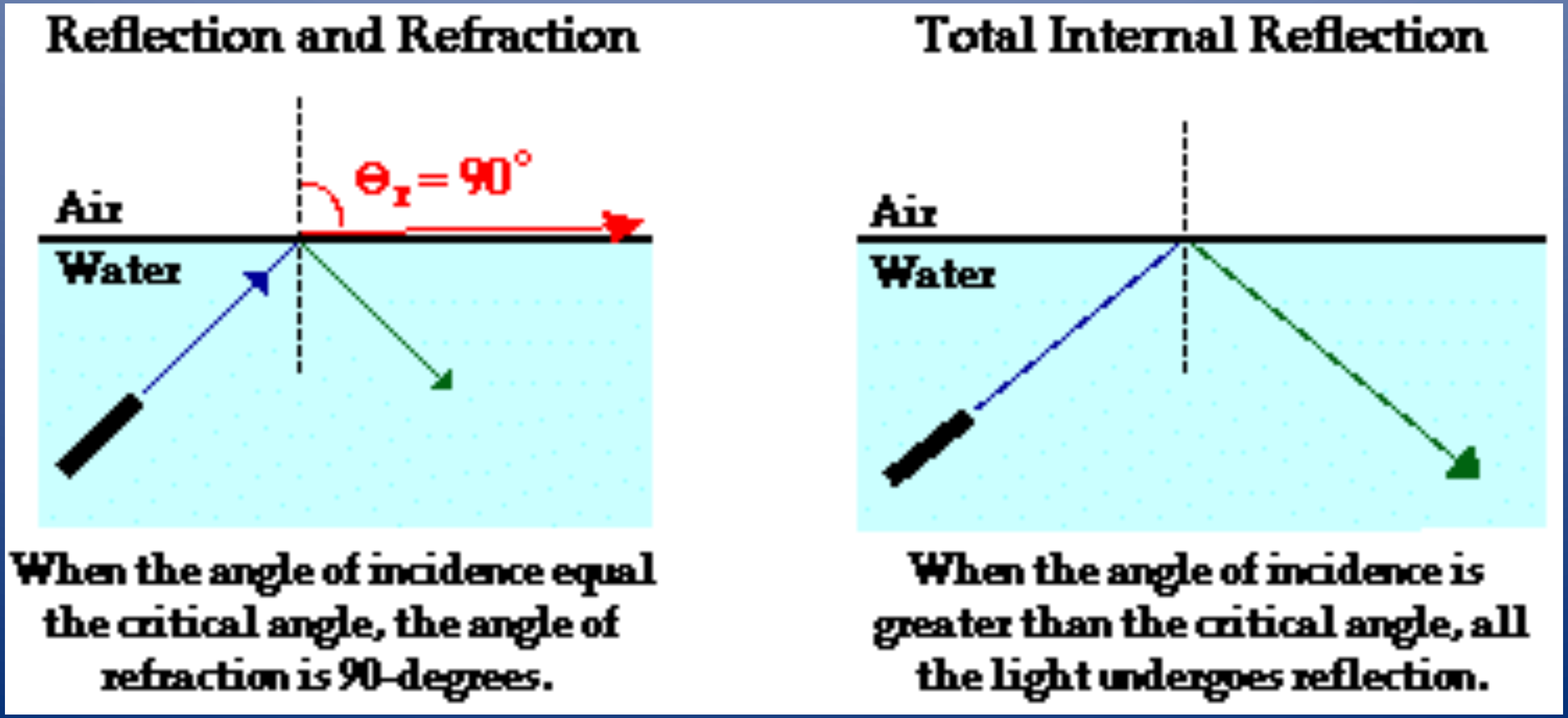
- The light from the pencil is refracted when it passes from the water into air, bending away from the normal as it moves from high to low refractive index.
- The light coming from the pencil tip appears to be coming from the apparent pencil tip as shown.



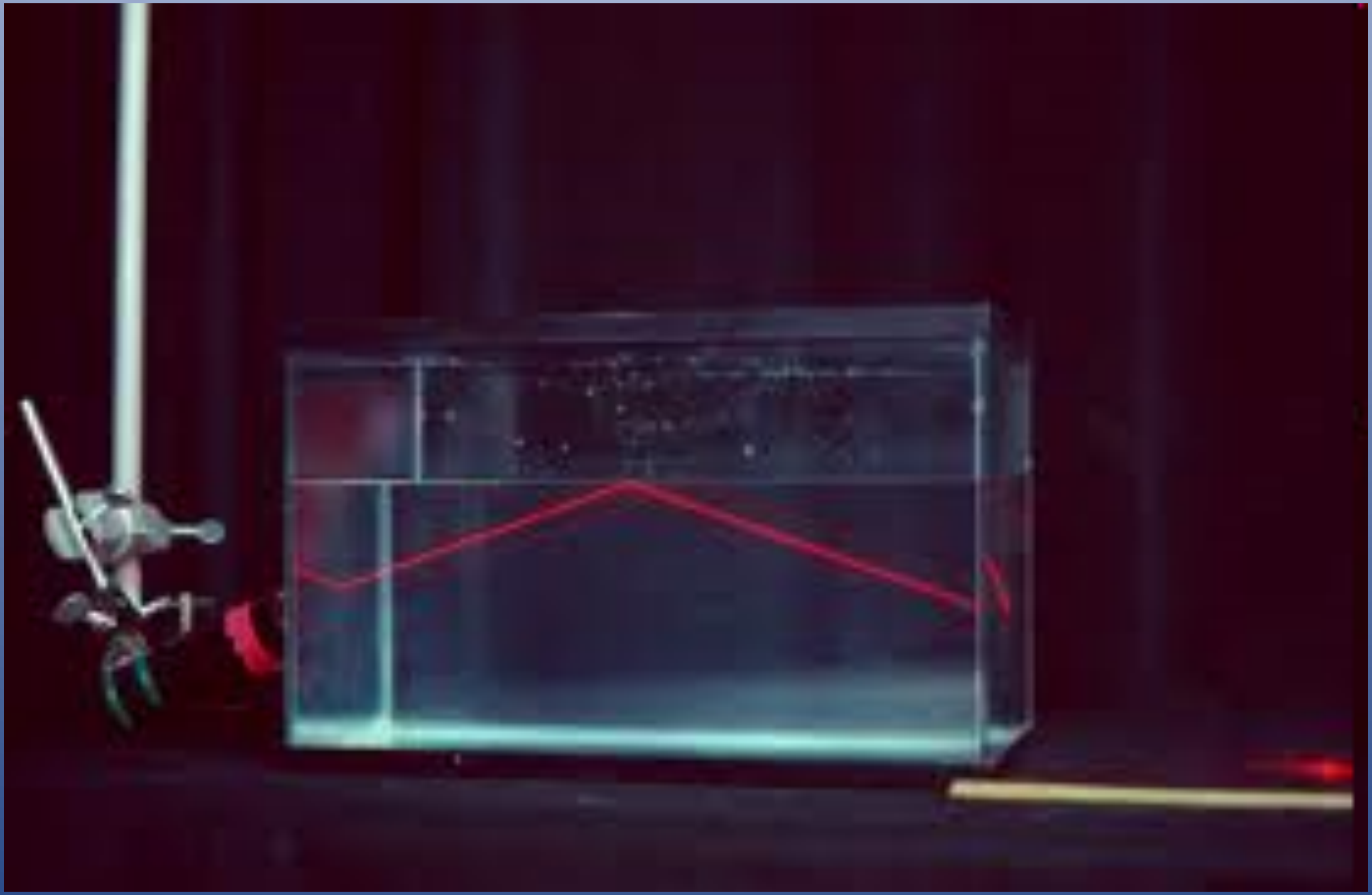
Total Internal Reflection (TIR)

TIR only takes place when both of the following two conditions are met:

- a light ray is in the more dense medium and approaching the less dense medium.
- the angle of incidence for the light ray is greater than the so-called critical angle.
- When the angle of incidence in water reaches a certain critical value, the refracted ray lies along the boundary, having an angle of refraction of 90-degrees.
- This angle of incidence is known as the **critical angle**; it is the largest angle of incidence for which refraction can still occur. For any angle of incidence greater than the critical angle, light will undergo total internal reflection.

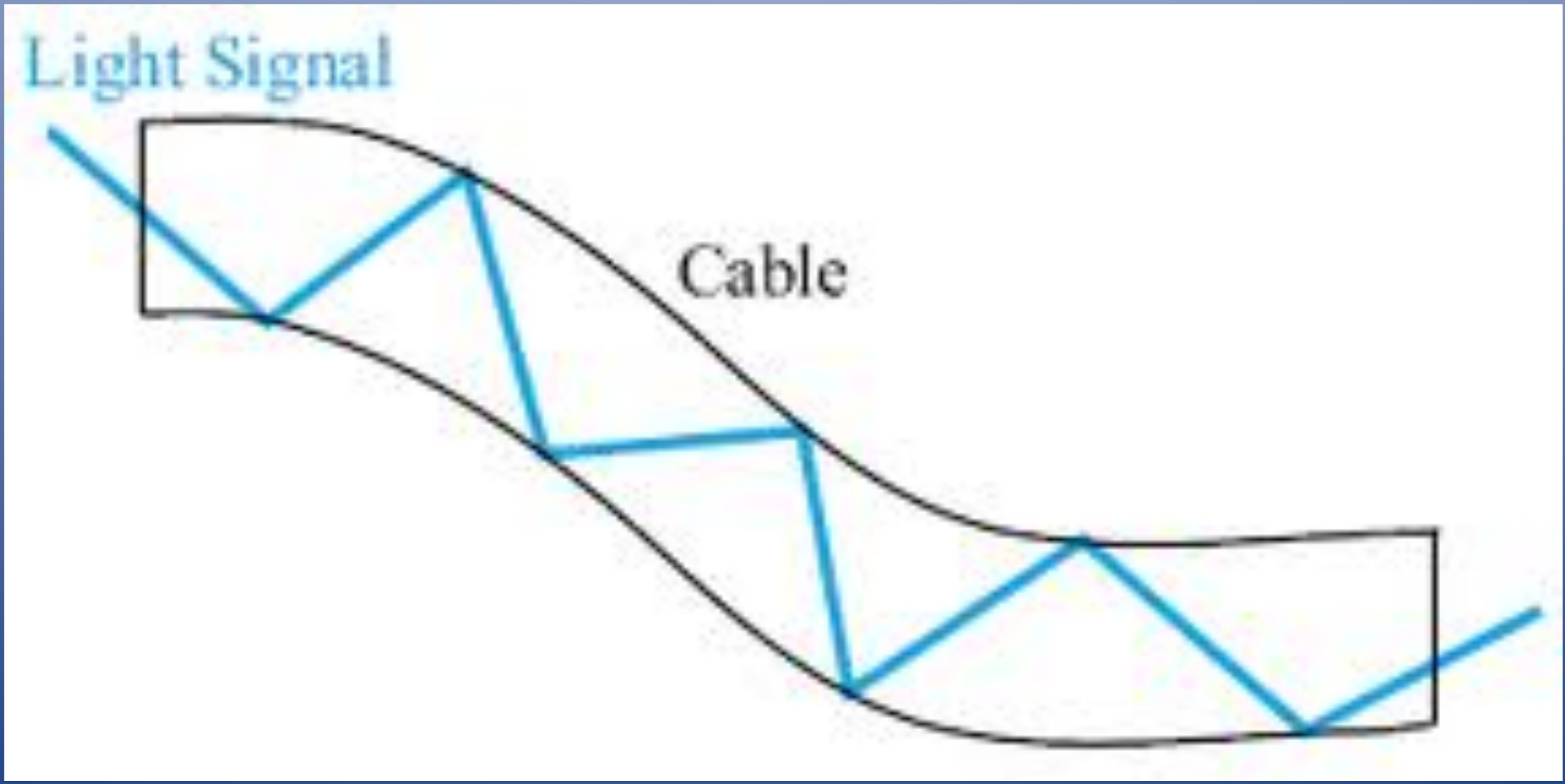


TIR



Critical angle

- So the critical angle is defined as **the angle of incidence that provides an angle of refraction of 90-degrees.** Make particular note that the critical angle is an angle of incidence value. For the water-air boundary, the critical angle is 48.6-degrees. For the crown glass-water boundary, the critical angle is 61.0-degrees. The actual **value of the critical angle is dependent upon the combination of materials present** on each side of the boundary.


Light Signal
Cable

Experiment 4 Apparent depth and measuring apparent depth

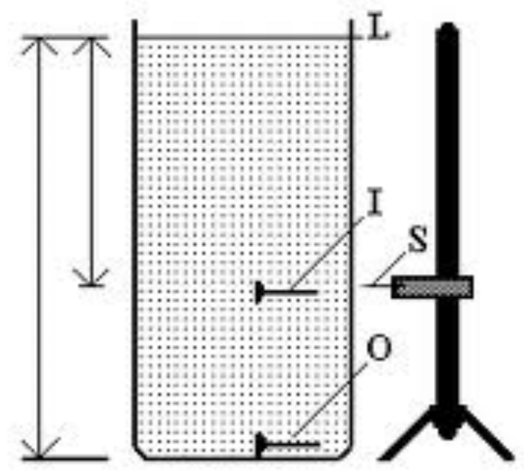
- **Aim:** to observe apparent depth and calculate the refractive index of water

$$\text{refractive index} = \frac{\text{real depth}}{\text{apparent depth}}$$

. This is equivalent to

$$n = \frac{\text{speed in water}}{\text{speed in air}}$$

28.124



Refractive index

- Vacuum 1.0000
- Air 1.000293
- Water 1.33
- Oleic acid 1.46
- Quartz 1.46
- Glycerine 1.47
- Paraffin 1.42
- Perspex 1.50
- Crown glass 1.517
- Carbon disulfide 1.63
- Flint glass 1.655
- Diamond 2.4173
- Ethanol 1.361
- Carbon dioxide 1.00450
- Benzene 1.3

DISAPPEARING GLASS

- Some liquids have an index of refraction very close to that of glass. When a glass object is lowered into the liquid, it almost disappears.
- Disappearing rock – Quartz is a clear rock crystal. Glycerine is a thick clear liquid. They have very similar refractive index's.
- Quartz (1.46) in glycerine (1.47).

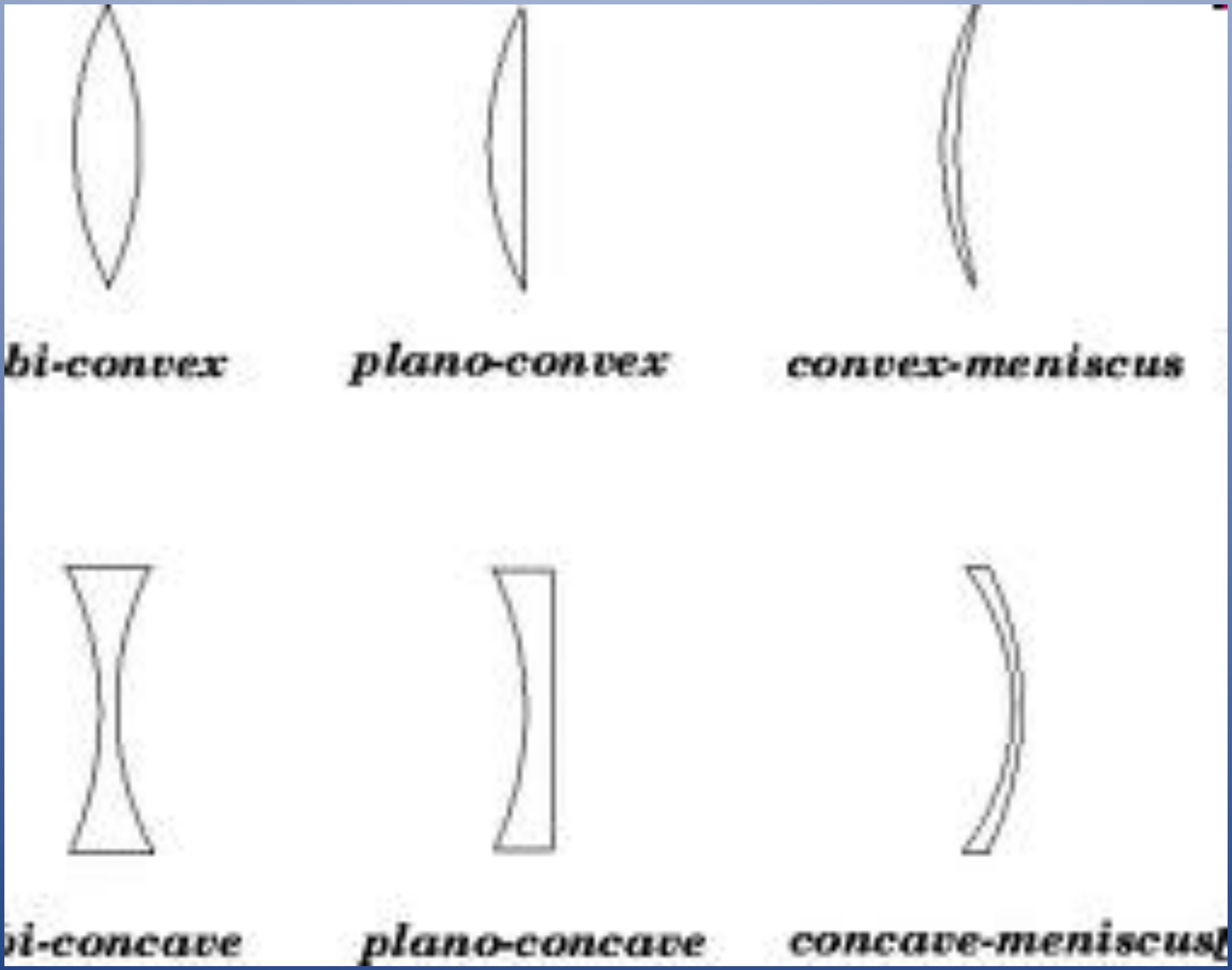
Refraction of Light – Shockwave activity

- http://www.physicsclassroom.com/shwave/refraction.cfm

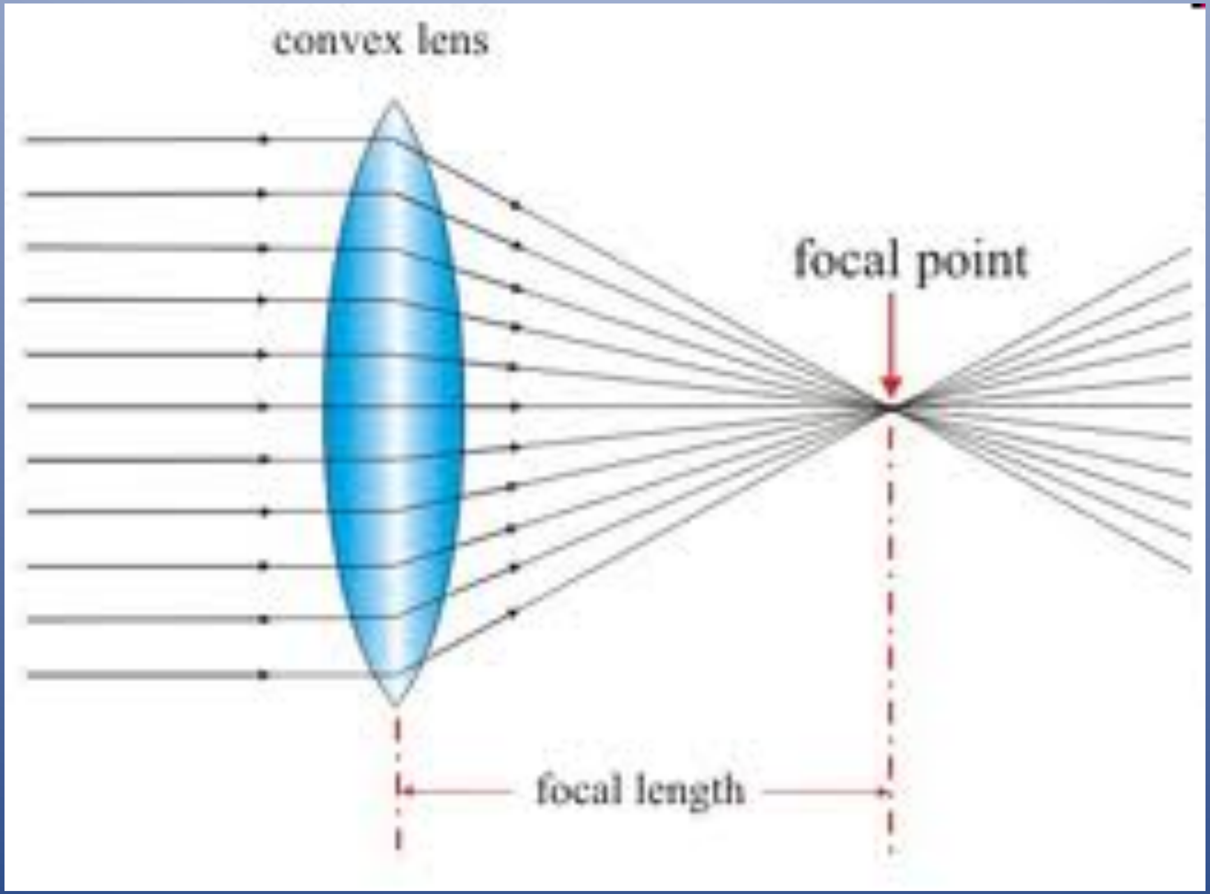
Lens behaviour and ray tracing

- Snell's Law
- http://www.physicsclassroom.com/class/refrn/U14l2b.cfm
- Image formation
- http://www.youtube.com/watch?feature=endscreen&NR=1&v=HGVUVFcyc6o
- http://www.youtube.com/watch?v=HGVUVFcyc6o&feature=related

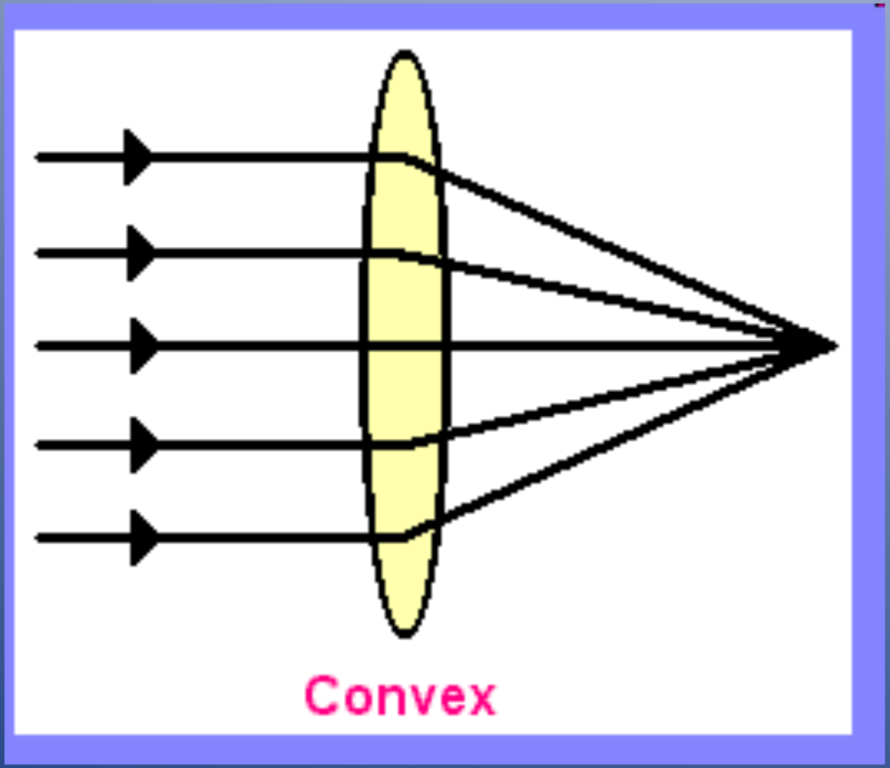
Different lenses



Convex lens



Refraction in lenses



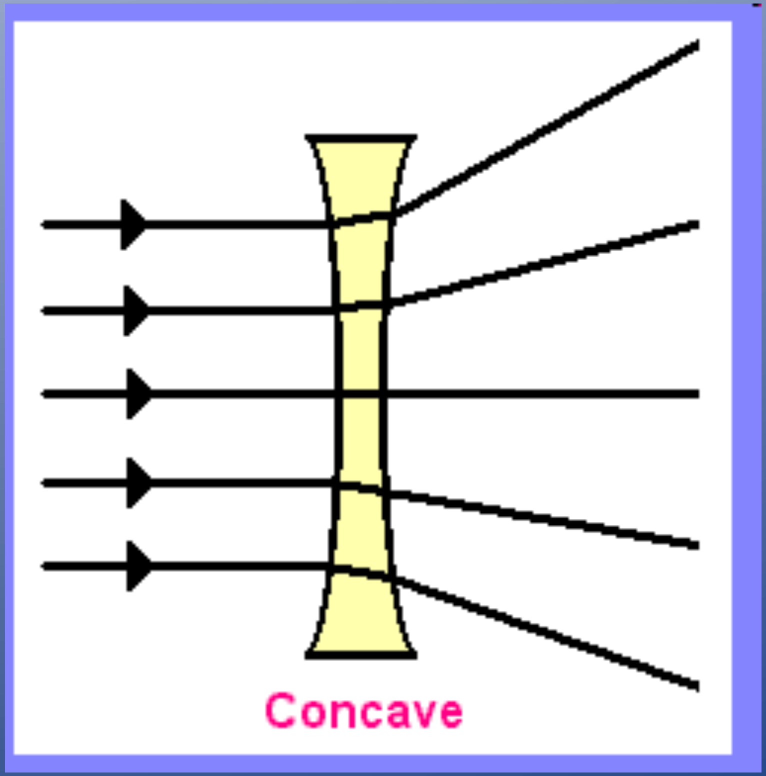
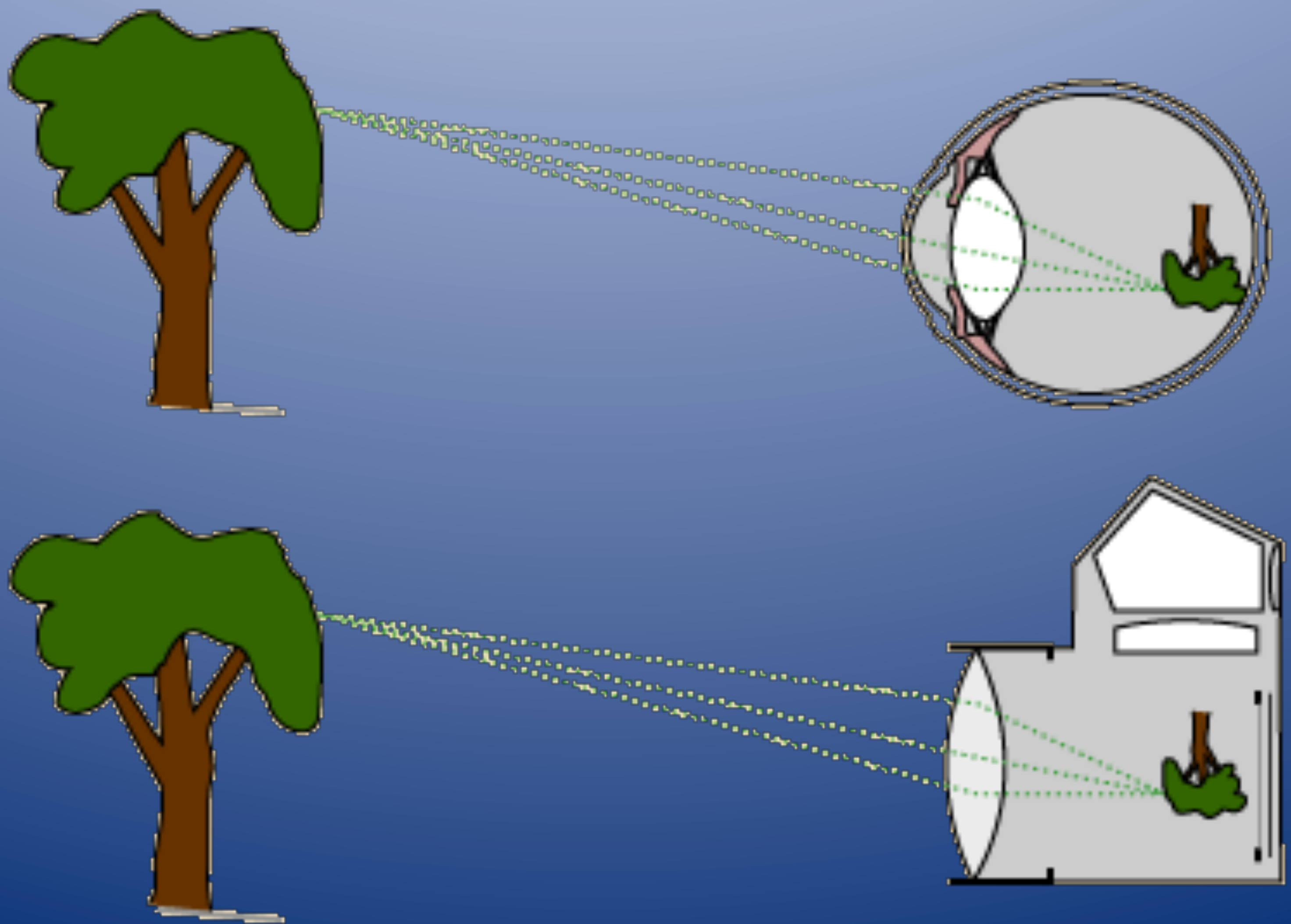
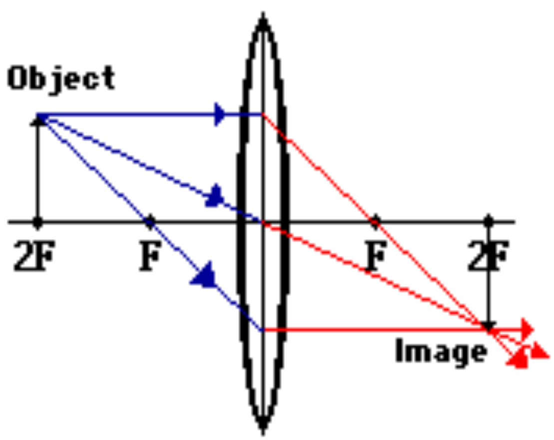


Image formation in the eye and a camera

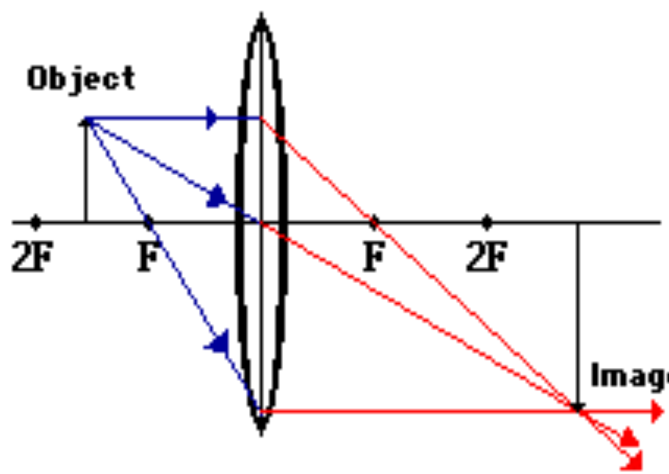


The three rules of refraction for a double convex lens

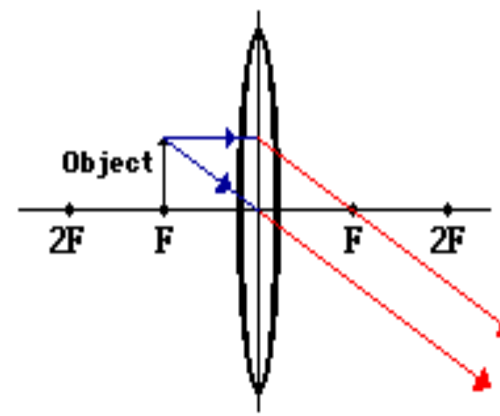
- 1. Any incident ray traveling parallel to the principal axis of a converging lens will refract through the lens and travel through the focal point on the opposite side of the lens.
- 2. Any incident ray traveling through the focal point on the way to the lens will refract through the lens and travel parallel to the principal axis.
- 3. An incident ray that passes through the centre of the lens will in effect continue in the same direction that it had when it entered the lens.



Ray Diagram for Object Located at 2F



Ray Diagram for Object Located Between F and 2F



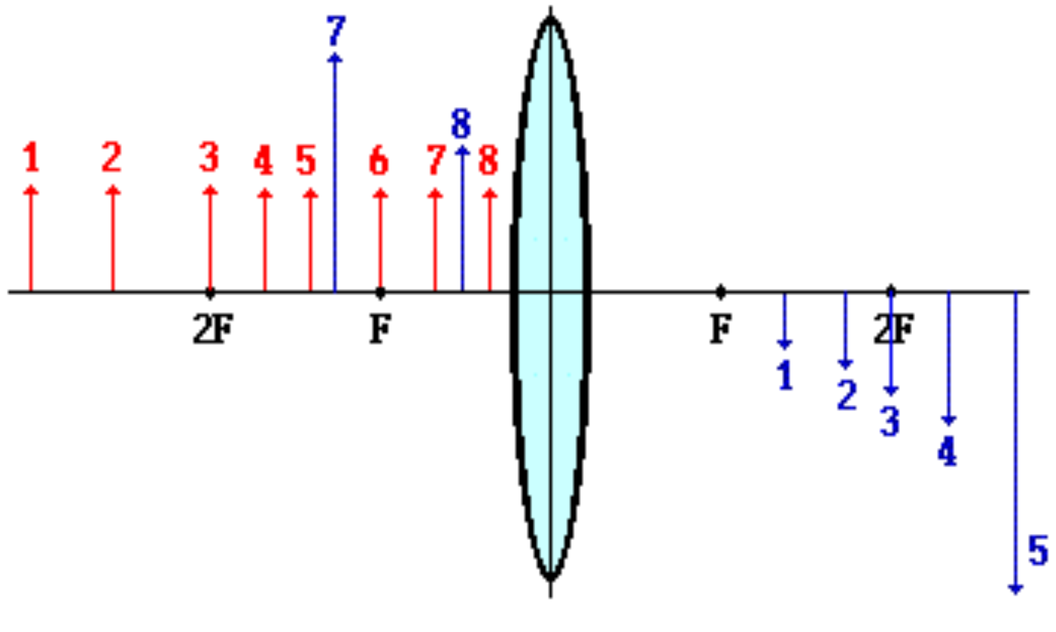
Ray Diagram for Object Located at F (an image is not formed)

Image formation websites

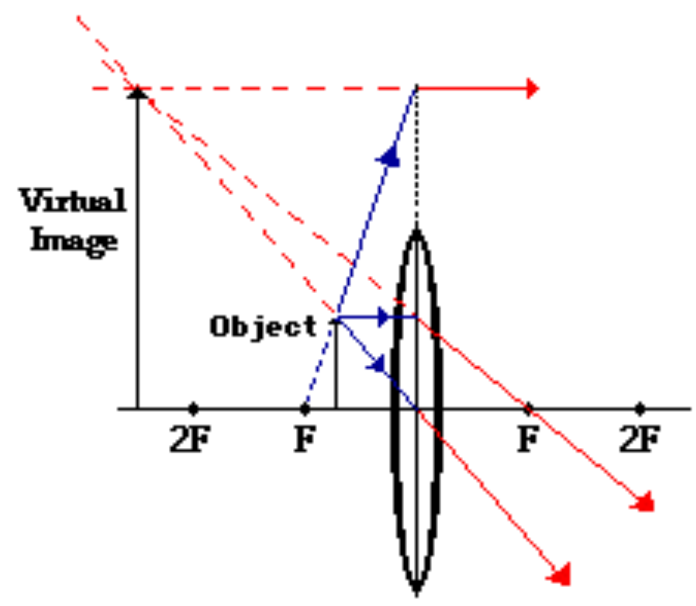
- http://enjoy.phy.ntnu.edu.tw/data/458/www/sims/geometric-optics/geometric-optics_en.html

(click marginal rays and virtual image)

- http://www.phys.hawaii.edu/~teb/optics/java/clens/index.html
- http://www.physicsclassroom.com/class/refrn/u14l5db.cfm
- http://www.physicsclassroom.com/shwave/lenses.cfm



Each of the numbered objects (except #6) has an image with the corresponding number; its relative location, size, and orientation are shown.



Ray Diagram for Object Located in Front of F

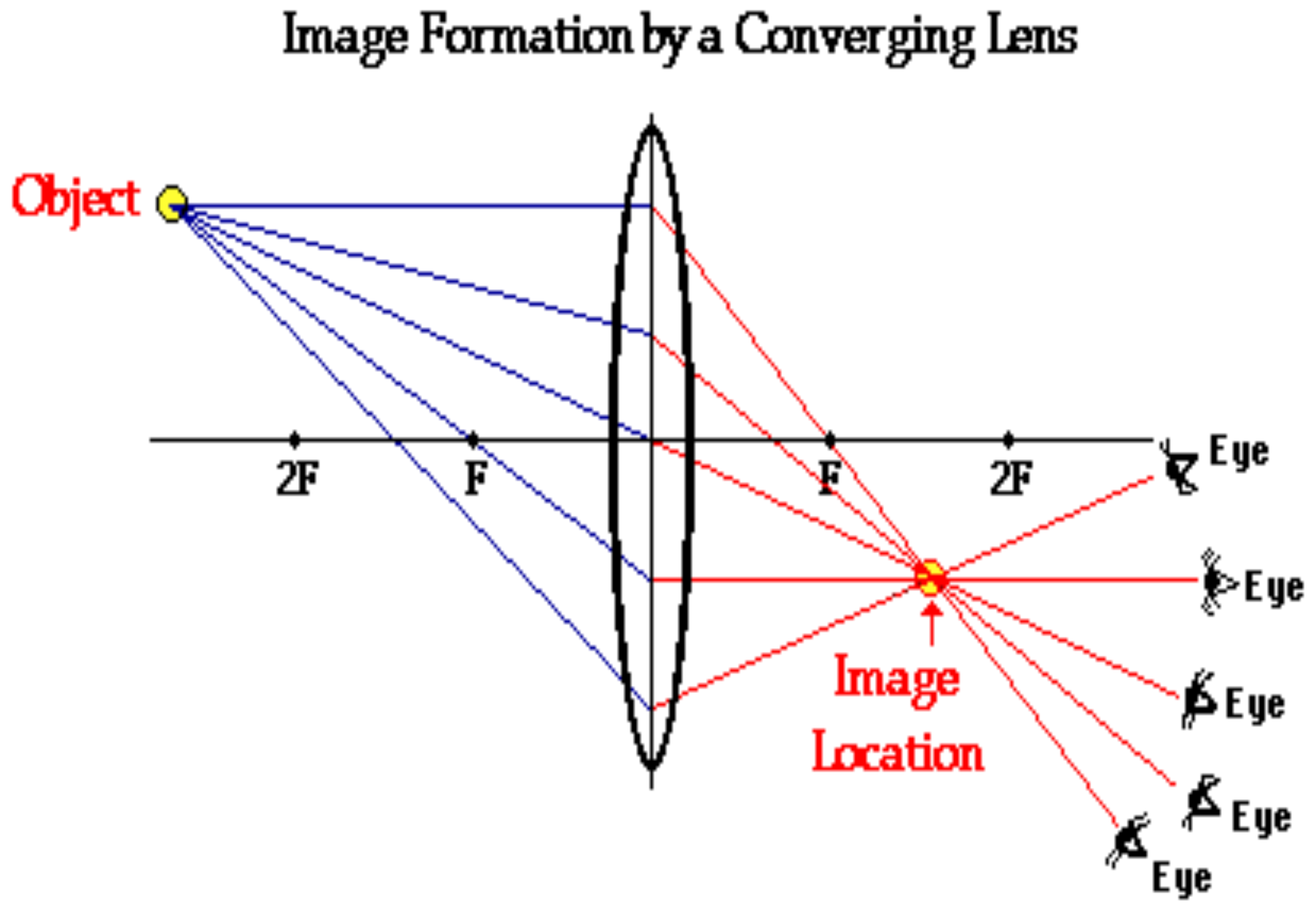
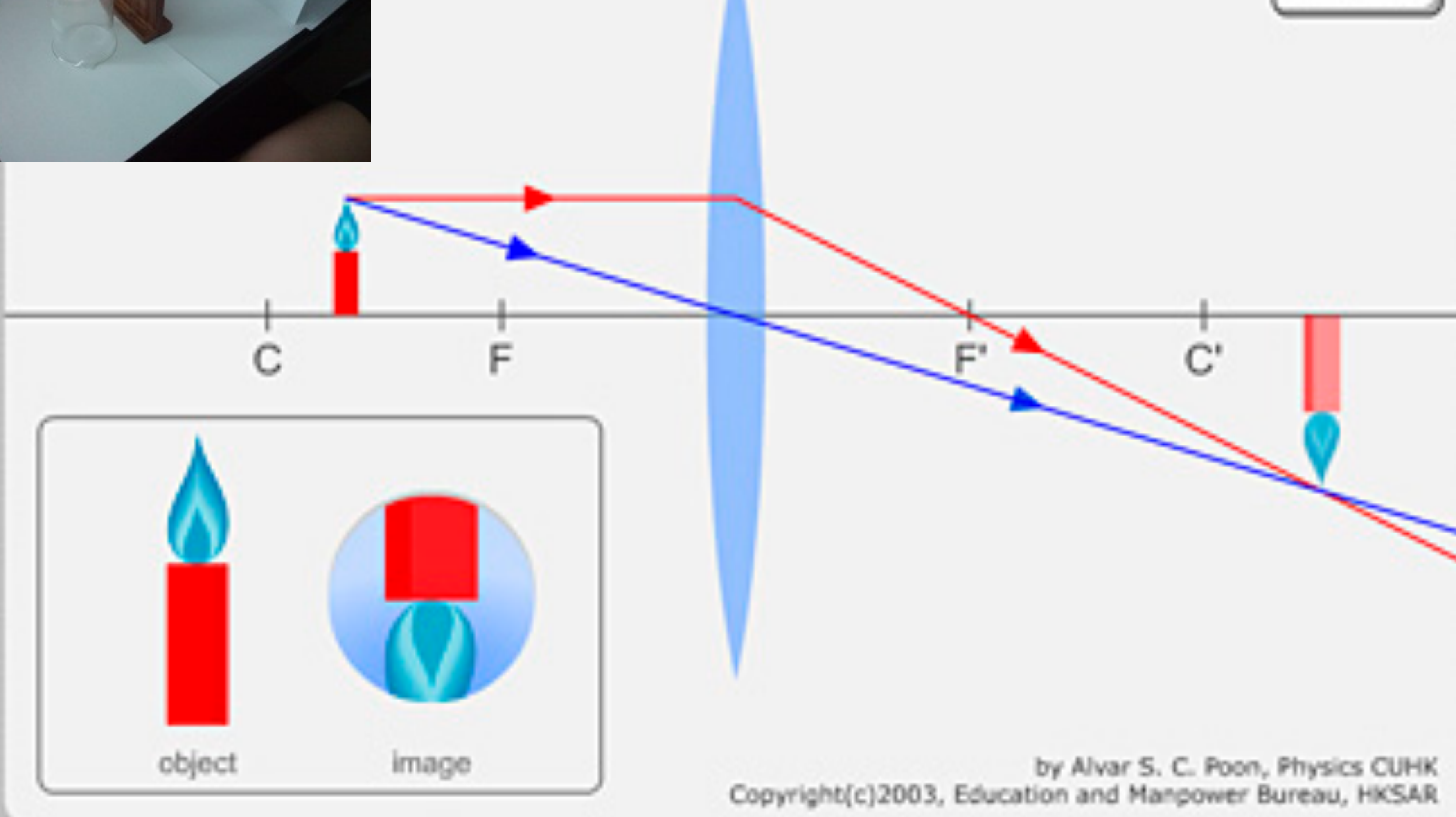
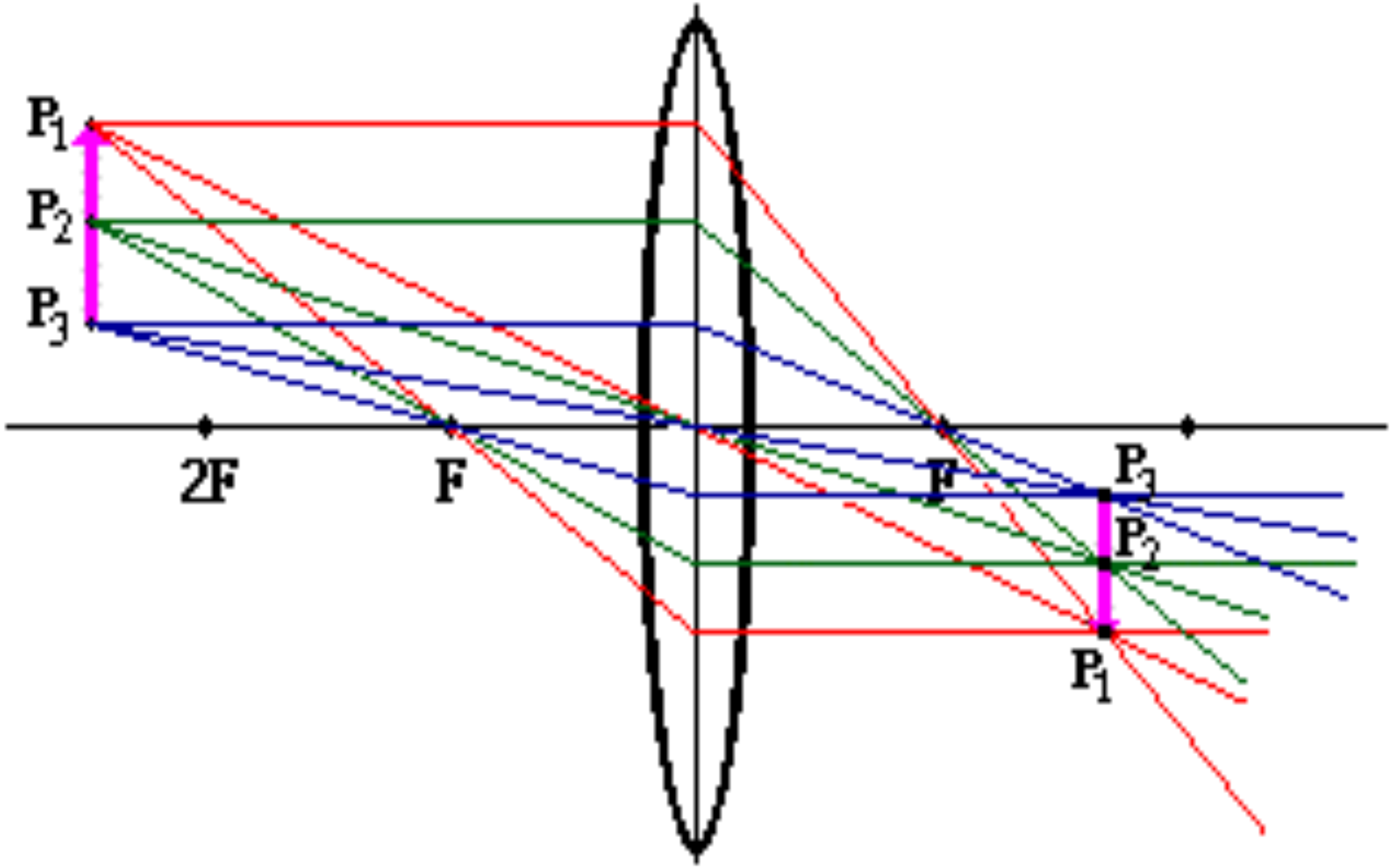


Image Formation by a Converging Lens
Object
2F
F
F
2F
Eye
Eye
Eye
Eye
Eye
Image
Location

IMAGE OF A CONVEX LENS



- Real image
-
-
- Virtual image
-
-
- Upright image
-
-
- Inverted image
-
-
- Enlarged image
-
-
- Diminished (or reduced) image

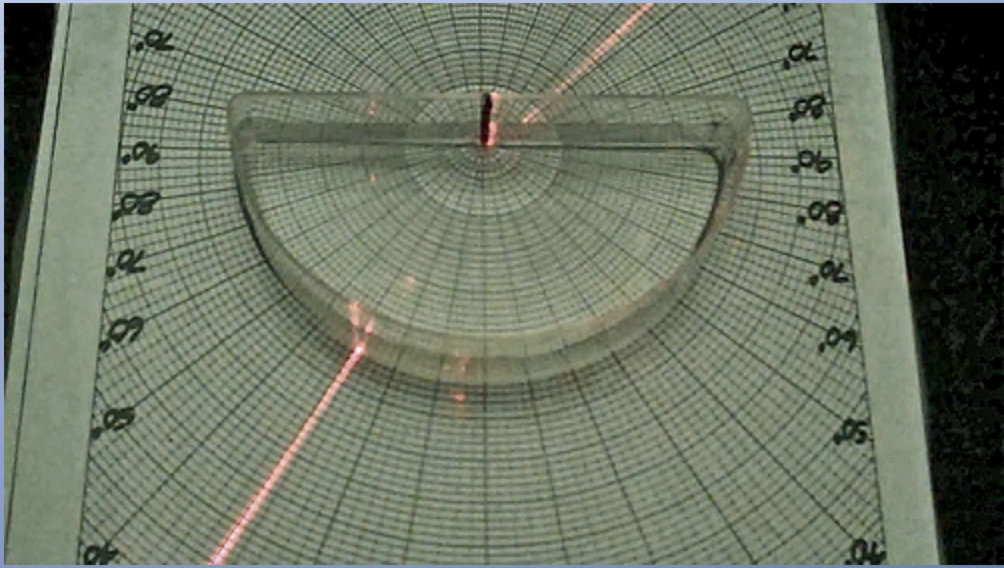


All the rays of light emanating from each individual point on the object will refract and intersect at a single point in space. An image is created - the image is merely a replica or reproduction of the object.

Snell’s Law

Extension

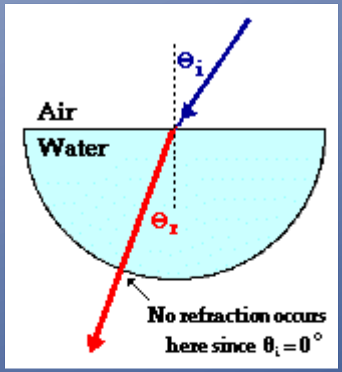
Refraction is the bending of the path of a light wave as it passes across the boundary separating two media. Refraction is caused by the change in speed experienced by a wave when it changes medium.



- Consider a hemi-cylindrical dish filled with water. Suppose that a laser beam is directed towards the flat side of the dish at the exact centre of the dish. The angle of incidence can be measured at the point of incidence. This ray will **refract,** bending towards the normal (since the light is passing from a medium in which it travels fast into one in which it travels slow – FST.
- Once the light ray enters the water, it travels in a straight line until it reaches the second boundary. At the second boundary, the light ray is approaching along the normal to the curved surface (this stems from the geometry of circles). The ray **does not refract** upon exiting since the angle of incidence is 0-degrees.
- The ray of laser light therefore exits at the same angle as the refracted ray of light made at the first boundary.

These two angles can be measured and recorded. The angle of incidence of the laser beam can be changed to 5-degrees and new measurements can be made and recorded. This process can be repeated until a complete data set of accurate values has been collected. The data below show a representative set of data for such an experiment.

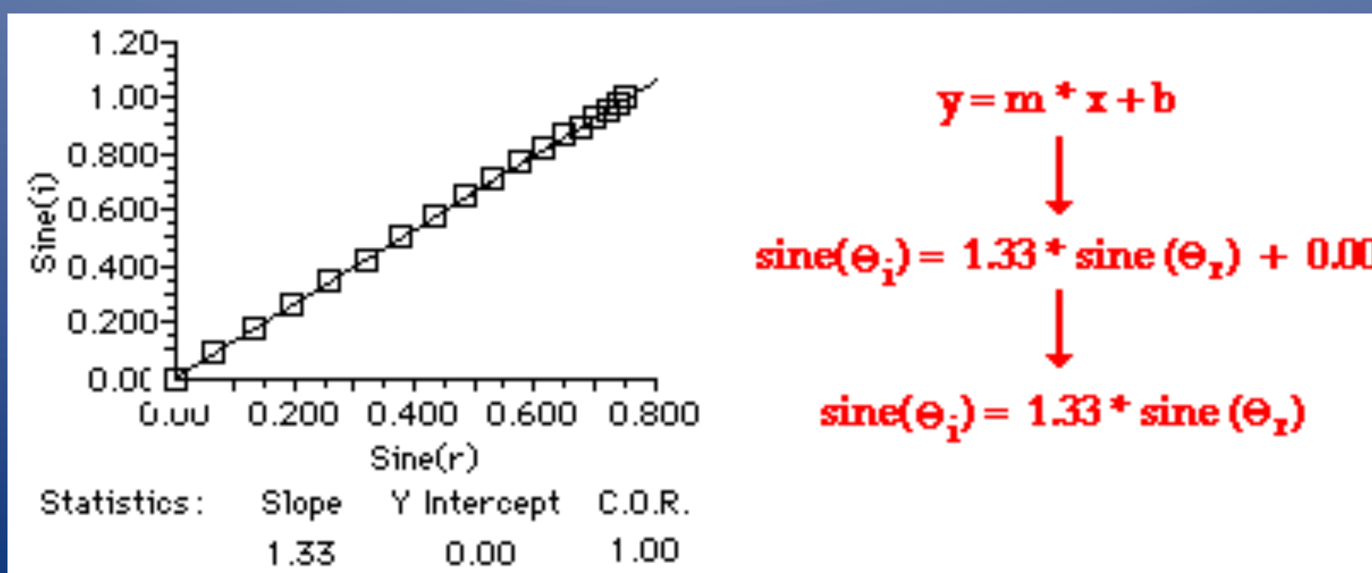
Angle of Incidence (degrees)	Angle of Refraction (degrees)
0.00	0.00
5.00	3.8
10.0	7.5
15.0	11.2
20.0	14.9
25.0	18.5
30.0	22.1
35.0	25.5
40.0	28.9
45.0	32.1
50.0	35.2
55.0	38.0
60.0	40.6
65.0	43.0
70.0	45.0
75.0	46.6
80.0	47.8
85.0	48.5



An inspection of the data above reveals that there is no clear linear relationship between the angle of incidence and the angle of refraction. For example, a doubling of the angle of incidence from 40 degrees to 80 degrees does not result in a doubling of the angle of refraction. If however, the sine of the angle of incidence and the sine of the angle of refraction were plotted, the plot would be a straight line, indicating a linear relationship between the sines of the important angles.

- If two quantities form a straight line on a graph, then a mathematical relationship can be written in **y = m*x + b** form. A plot of the sine of the angle of incidence vs. the sine of the angle of refraction is shown below.
- The equation relating the angles of incidence ("theta i") and the angle of refraction ("theta r") for light passing from air into water is given as

$$\text{sine}(\Theta_i) = 1.33 * \text{sine}(\Theta_r)$$



- Observe that the constant of proportionality in this equation is 1.33 - **the index of refraction value of water.**
- If the semi-cylindrical dish full of water was replaced by a semi-cylindrical disk of Plexiglas, the constant of proportionality would be 1.51 - **the index of refraction value of Plexiglas.**
- This is not just a coincidence. The same pattern would result for light traveling from air into any material. Experimentally, it is found that for a ray of light traveling from air into some material, the following equation can be written.

$$\mathrm{sine}(\Theta_i) = n_{material} * \mathrm{sine}(\Theta_r)$$

- where $\mathbf{n_{material}}$ **= index of refraction of the material**

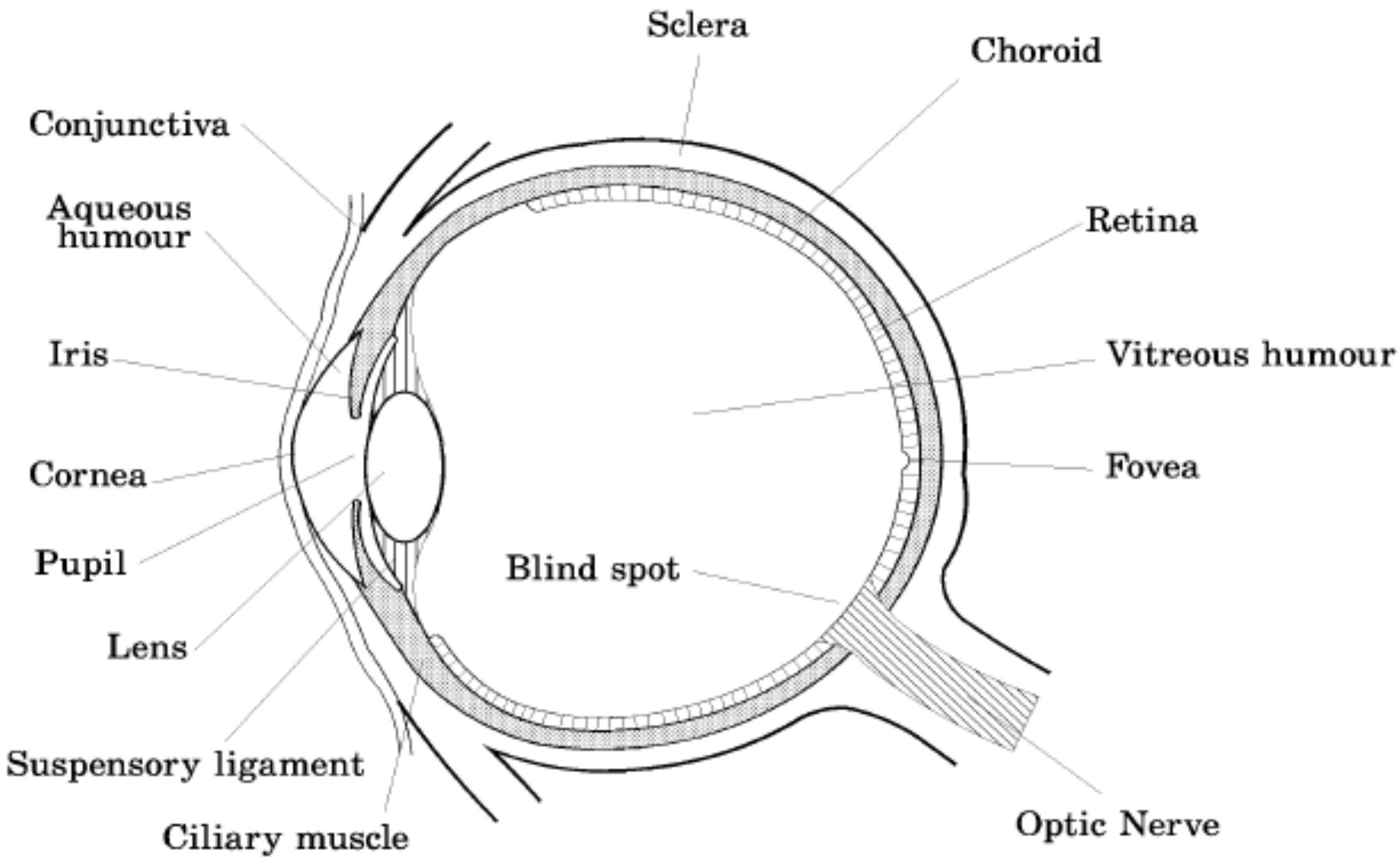
$$n_i * \text{sine}(\theta_i) = n_r * \text{sine}(\theta_r)$$

- where θ_i ("theta i") = angle of incidence
- θ_r ("theta r") = angle of refraction
- $\mathbf{n_i}$ = index of refraction of the incident medium
- $\mathbf{n_r}$ = index of refraction of the refractive medium
- This relationship between the angles of incidence and refraction and the indices of refraction of the two media is known as **Snell's Law**. Snell's law applies to the refraction of light in any situation, regardless of what the two media are.

The eye

- Parts of the eye
- How the eye works
- Eye dissection

The Mammalian Eye



VITREOUS HUMOUR Clear liquid that fills the eye.

CILIARY MUSCLE A ring shaped muscle for controling the focus of the lens

RETINA The retina is a lining of cells that convert light into nervous signals that are sent to the brain.

FOVEA The fovea is the most sensitive part of the retina.

BLIND SPOT Where the retina's nerve cells meet.

CONJUNCTIVA This is a thin, transparent layer for protection.

SCLERA The white of the eye. Provides blood and support.

PUPIL The opening through which light enters.

OPTIC NERVE The eye's connection to the brain.

LENS Focuses the light onto the retina.

IRIS Controls the amount of light entering the eye.

CORNEA & AQUEOUS HUMOUR The cornea is a tough bag of liquid called aqueous humour. It allows the iris to move.

SUSPENSORY LIGAMENT Holds the lens in place.

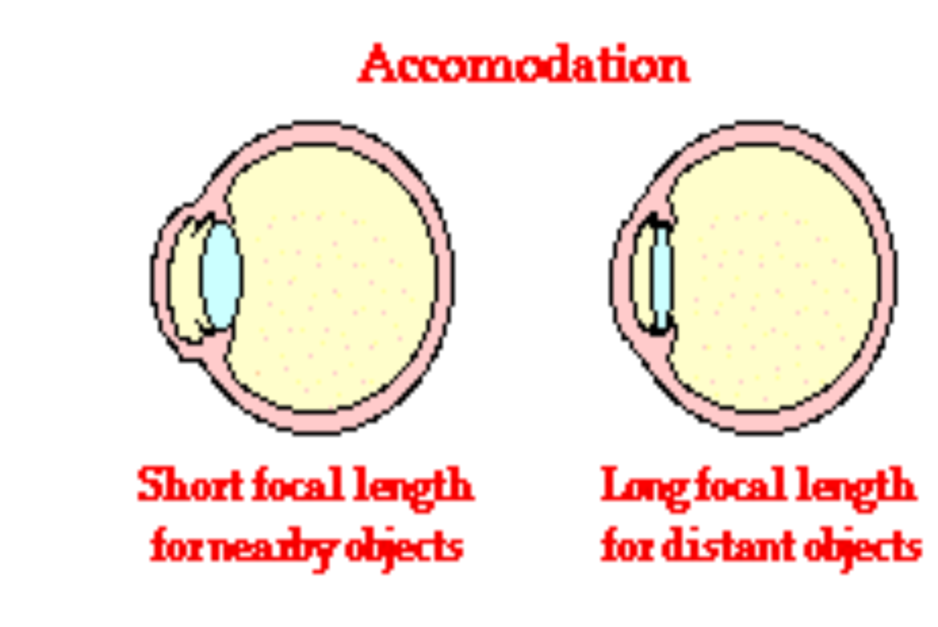
CHOROID Tissue for supporting the retina. Contains many capillaries.

Eye dissection

- http://www.eschoolonline.com/company/examples/eye/eyedissect.html

The eye videos

- http://www.youtube.com/watch?v=UgYEyNZ3ea0&feature=relmfu
- http://www.youtube.com/watch?v=gvozcv8pS3c&feature=related



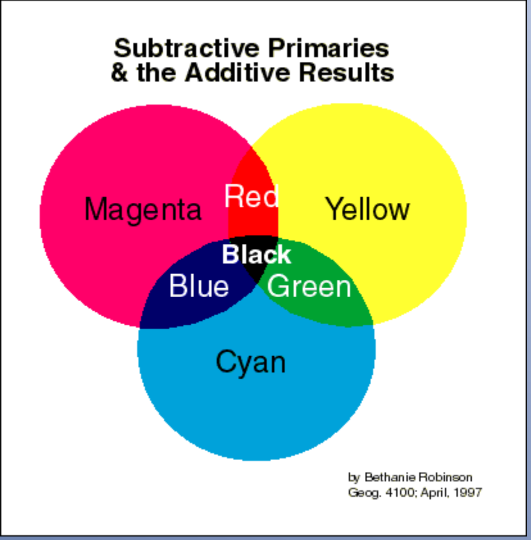
Colour blindness

- http://www.toledo-bend.com/colorblind/Ishihara.asp

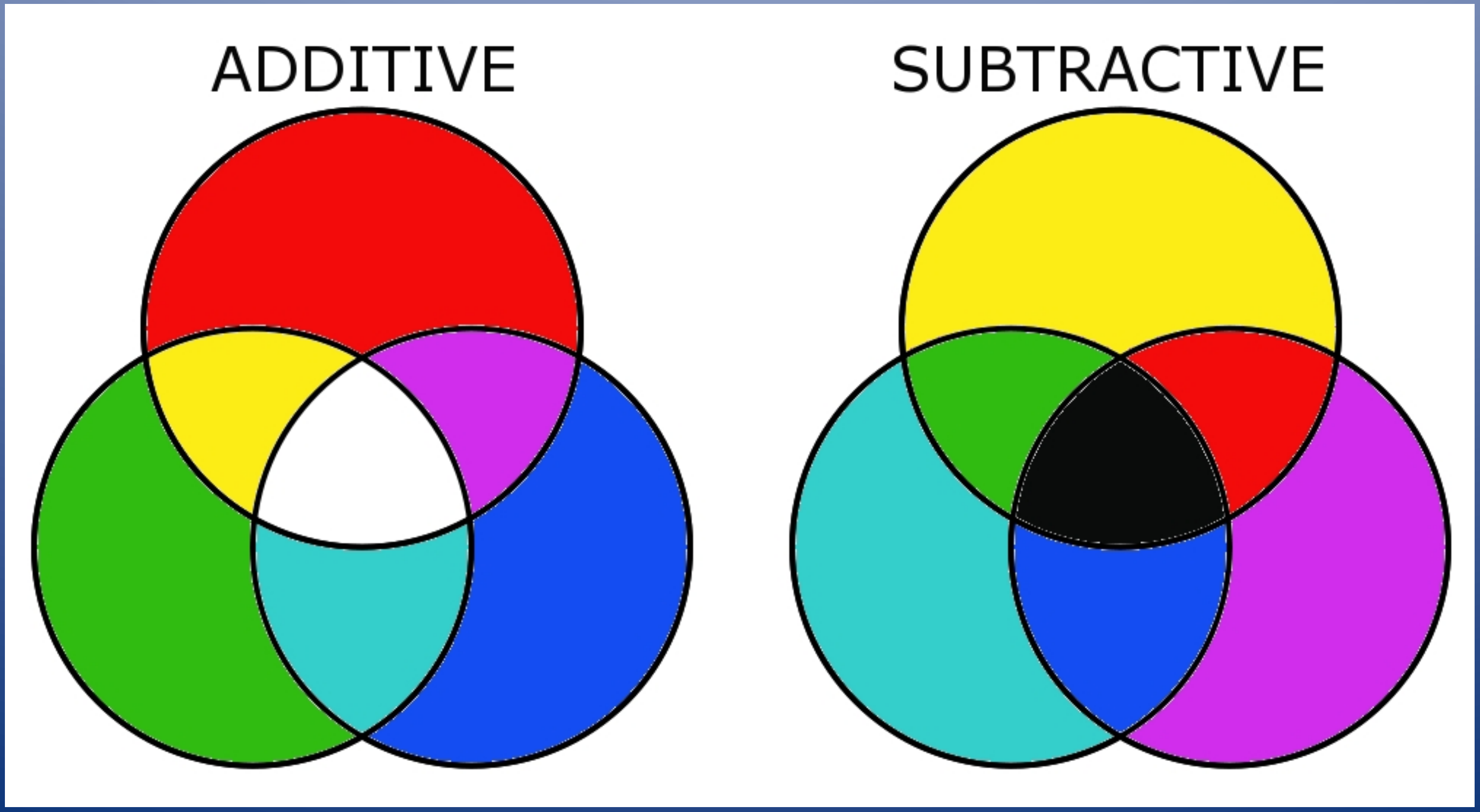
- Where are the rods and cones found in the eye?
- 20. What is the job of the rods?
- 21. What is the problem called when you have difficulty seeing long distances?
- 22. What is the problem called when you have difficulty seeing close up?
- 23. Which type of problem needs a concave lens to help solve it?

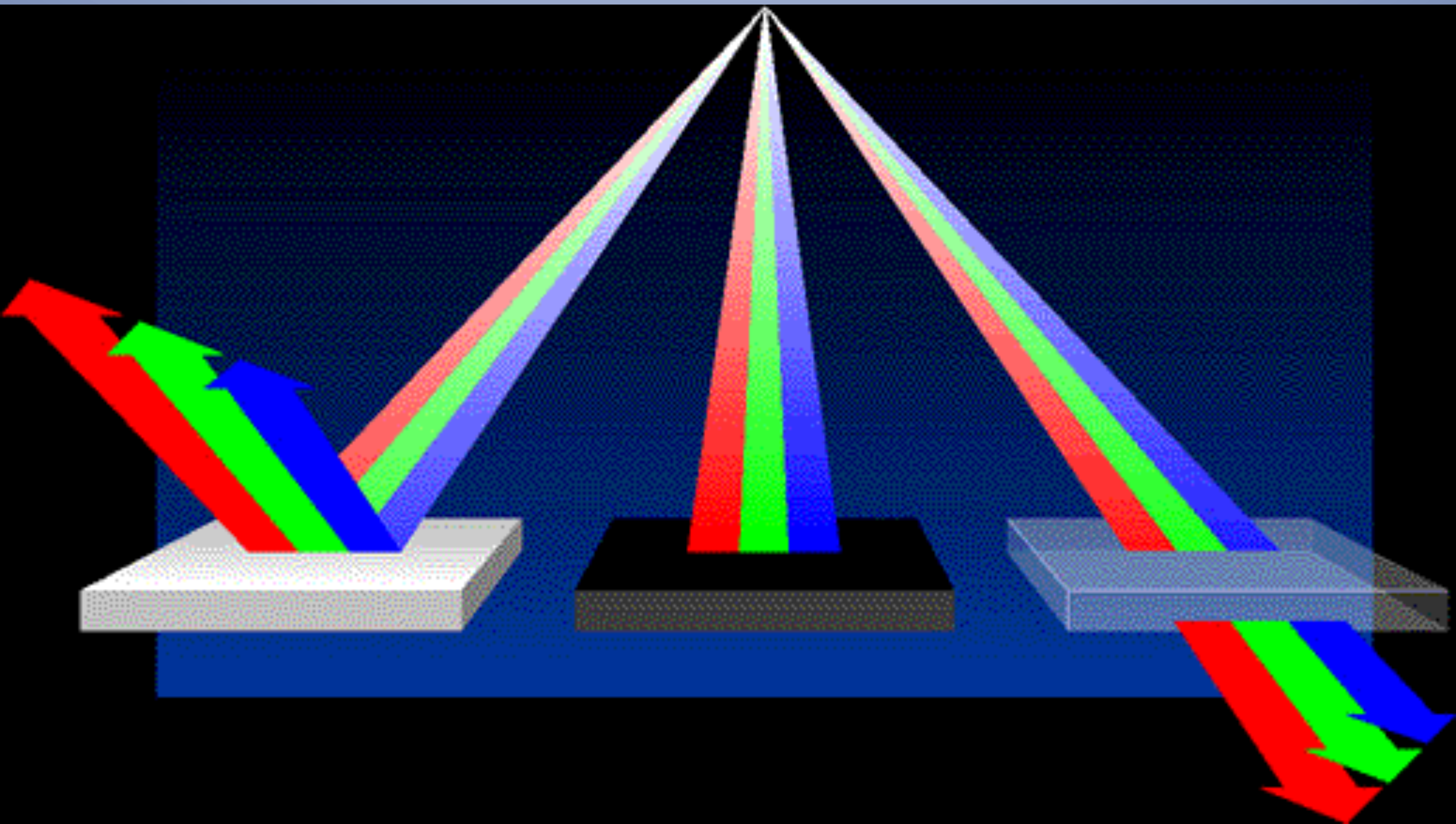
Colour

- Addition and subtraction of colours
- <u>Primary Colours</u>: Blue, green and red
- <u>Secondary Colours</u>: Cyan, magenta and yellow



- Describe what a red filter does.





- **Transparent objects absorb, or filter out, components of the visible spectrum out of the light passing through.**
- The cyan coloured object absorbs all of the red component of white light, allowing only blue and green to pass through. Blue and green light combine to form cyan.

Video - Colours

- http://www.youtube.com/watch?v=LoL1Mn5v6GY
- Electromagnetic radiation and colour
- http://www.youtube.com/watch?v=o0NyvzhVrIE&feature=relmfu
- Colour subtraction http://www.physicsclassroom.com/class/light/u12l2e.cfm