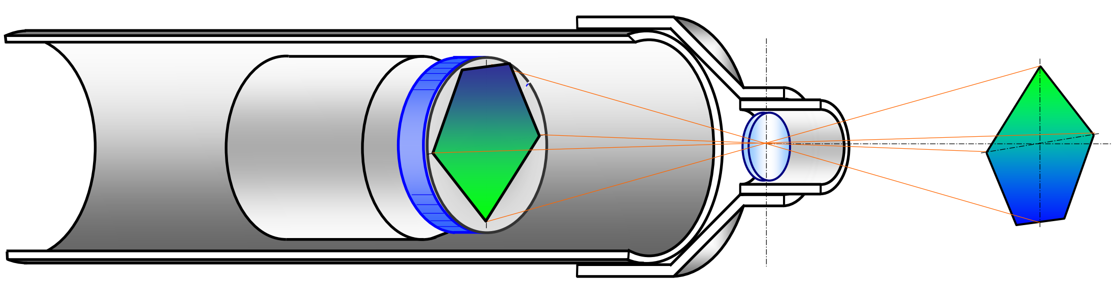
centre de développement pédagogique
pour la formation générale en science et technologie

Working document

Theoretical capsule about geometrical optics
(Intended for personnel)



October 2014

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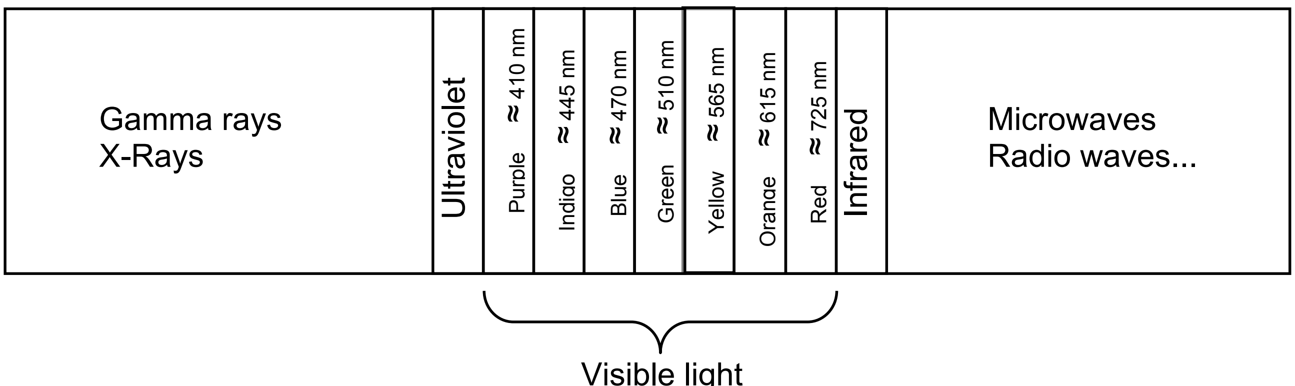
This document is a documentation tool for personnel within the framework of the "Model of the eye" teaching sequence for secondary three. The material broached covers the concepts required for the activities. The subject will be covered in depth in secondary five physics.

Electromagnetic spectrum

Light is an electromagnetic wave as are radio waves or microwaves, for example. What distinguishes light from other electromagnetic waves is its wave length. This wave length is measured in nanometres (nm), namely 1 millimetre divided by 1 million (1 nanometre = 10^{-9} m). A rainbow, for example, shows all the waves lengths of light (colours). Here is a simplified diagram of the electromagnetic spectrum.



Light rays

Like all electromagnetic waves, light travels in straight lines in a vacuum. In a classroom where temperature is stable, we can consider that light will travel in a straight line. In class, we will call light that travels in a straight line "light rays" or "rays of light".

Reflection

In some situations, however, light may be deviated. That's exactly what happens when we look at ourselves in the mirror. First, the light leaves a light source (light bulb), hits our skin and goes back toward the mirror. The light thus reflected hits the mirror and comes back to our eyes. In both these cases, we call it **reflection.** Even though our eyes or our glasses are not made of mirrors, the phenomenon of reflection can help us understand certain properties of light.

Animation: http://www.sciences.univ-nantes.fr/sites/genevieve_tulloue/optiqueGeo/miroirs/miroir_plan.html (In French)

Refraction

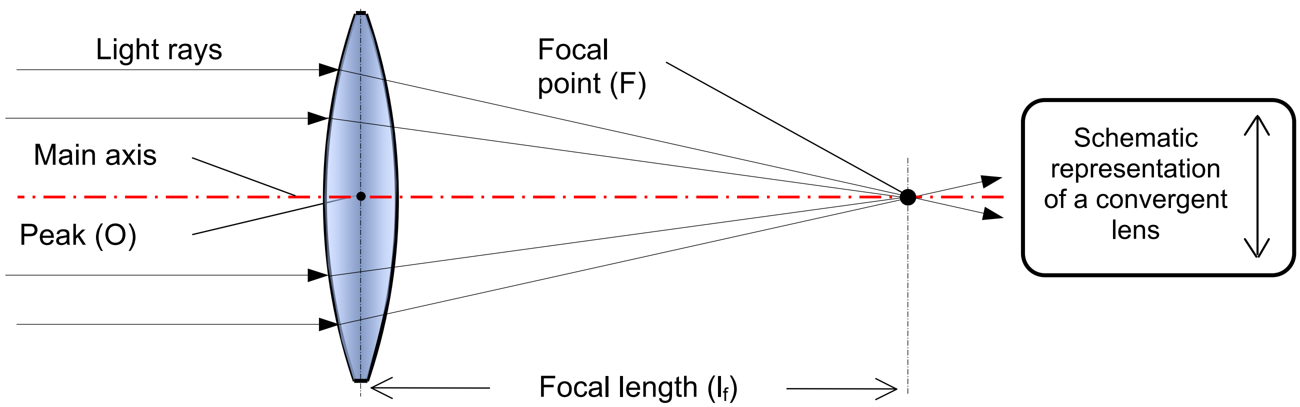
In the photo here, the screwdriver seems broken. This is due to the fact that the light changes direction passing from water to air. This phenomenon also happens with glass, air and many other transparent substances. The appearance of a rainbow is also due to the fact that the light is deviated on its path. This phenomenon, called refraction, is also the reason for the formation of mirages.
In the case of the eye and corrective lenses (glasses) it is the phenomenon of refraction that changes the direction of the propagation of light.

Animation: http://www.sciences.univnantes.fr/sites/genevieve_tulloue/optiqueGeo/dioptres/dioptre_plan.html (In French)

Convergent lenses

As its name indicates, the convergent lens concentrates light rays toward a point called the focal point. Have you ever used a magnifying glass to burn a piece of paper? The human eye, as well as some corrective lenses are good examples of convergent lenses.

- A convergent lens is thicker in the middle than at the sides.
- The **peak (O)** or **optical center** of the lens is its center.
- A convergent lens makes the light coming from a distant object converge (concentrate) at the **focal point (F).** Here, the object is located at the left, in the distance. In reality, there are two focal points: the object focal point (F_o) and the image focal point (F_i).
- The **focal length (l_f)** is the distance between the peak of the lens and the focal point. The shorter the focal length, the greater the curvature of the lens, the more it deviates the light rays.

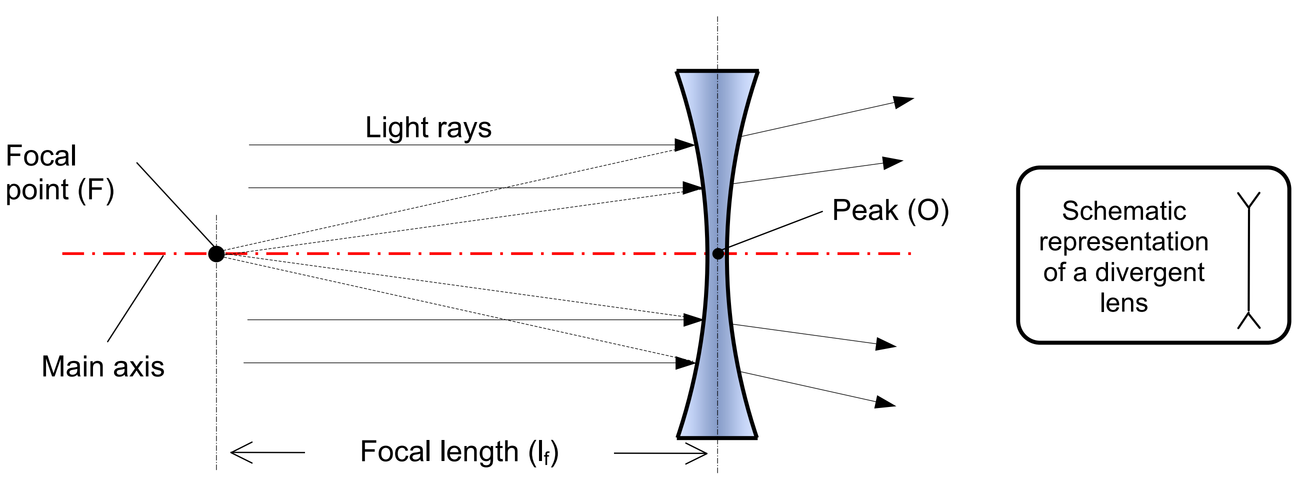


Animation: http://ekladata.com/nW5sWMyodLC5KTE7BzxP2qVaodA/lentille_convergente.swf (In French)

Divergent lenses

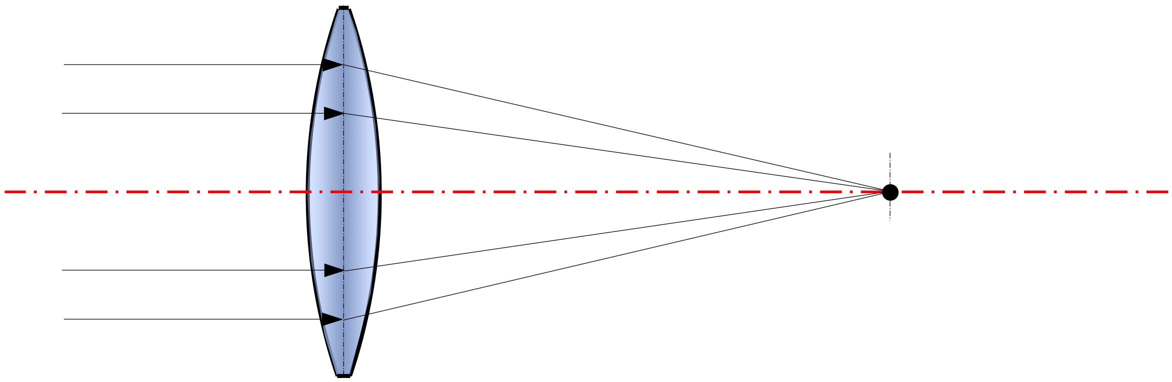
As for the divergent lens, it only diverts (disperses) light rays.

- A divergent lens is thicker on the edges than at the center.
- The **peak (O)** or **optical center** of the lens is its center.
- A divergent lens diverts the light coming from an object.

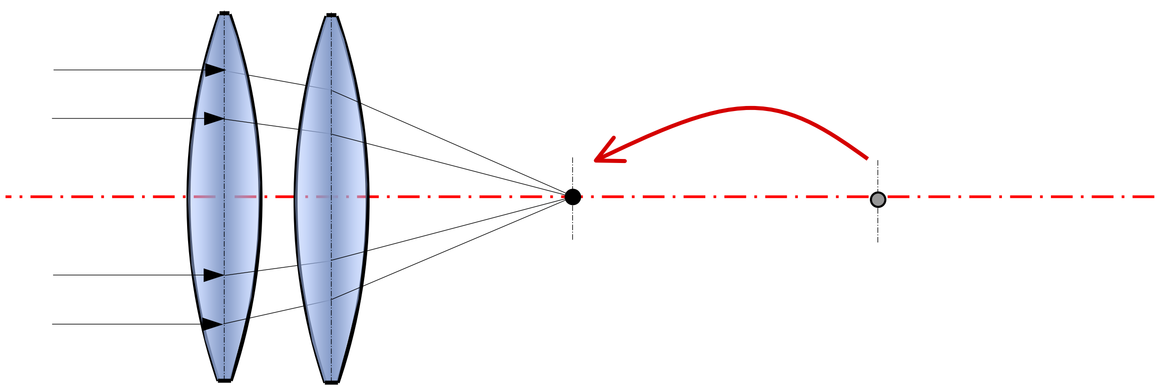


Combining lenses

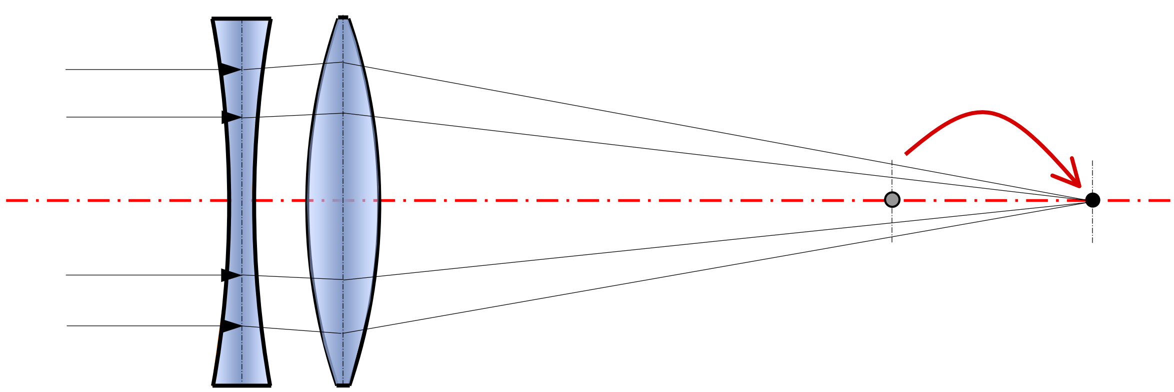
- Here is a convergent lens, which concentrates the rays coming from a distant object at the focal point. A convergent lens makes the rays converge at the focal point.



- Adding a second convergent lens makes the rays converge even more and brings the focal point closer to the lenses.



- The addition of a slightly divergent lens makes the rays converge more slowly. This distances the focal point from the lenses.

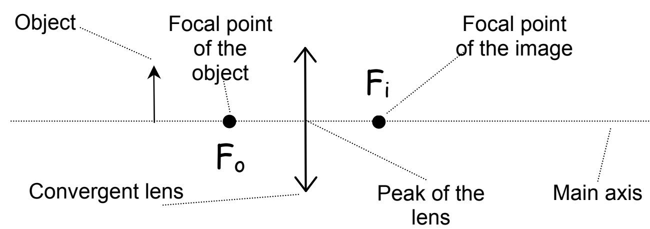


Animation: http://www.sciences.univ-nantes.fr/sites/genevieve_tulloue/optiqueGeo/instruments/correction.html (In French)

Locating images using diagramming

To clearly understand the function of the eye and of lenses, it is useful to graphically foresee the position of an image formed in the presence of an object. To do so, we will only draw the main light rays. To better understand, let's see what happens with a flat mirror. When we look into a mirror, the image that we see is formed from innumerable light rays reflected by its surface. When we want to draw the phenomenon of an image appearing, however, it is impossible for us to draw an infinite numbers of rays. We will therefore only draw the most important rays. We will do the same with convergent lenses.

In addition, in geometrical optics, there are two types of images: the real image and the virtual image. The image that appears on a flat mirror is a virtual image, since we see it by putting our eyes in the rays of light. In the case of a film projector, it is a real image, since the image is formed on a screen. In the case of the eye, we are in the presence of a real image, since the retina of the eye acts as a screen.



By drawing the light rays to determine the position of the image, you will realise that it is not always formed at the focal point of the lens. The image does form, however, where the rays converge (meet).

Here is how to determine the position of a real image generated by a convergent lens.

1. Draw a first ray starting from a characteristic point of the object (end of the arrow) and going through the peak

   Note: The direction of this ray is practically unchanged, since the faces of the lens are virtually parallel at this point.

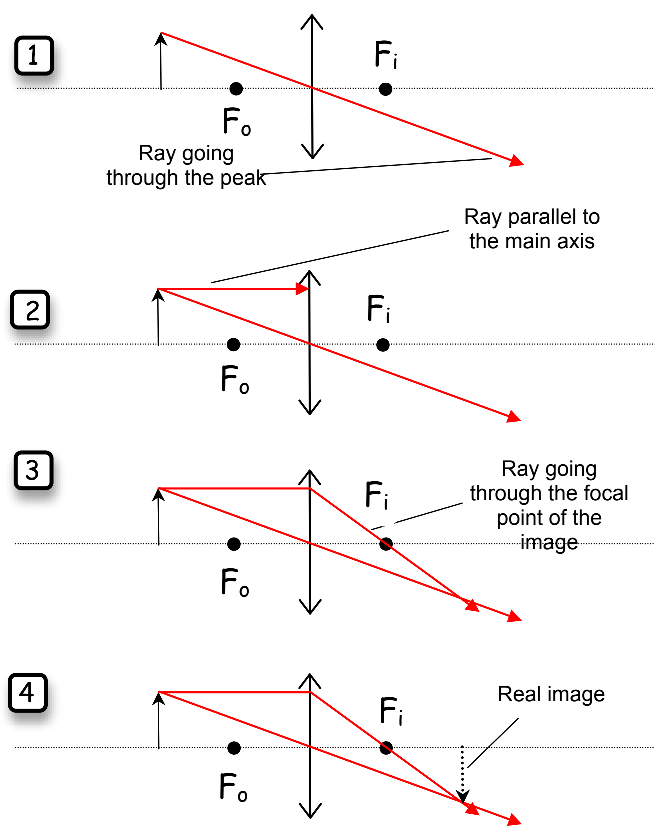
2. Start drawing the second ray parallel to the main axis

   Note: The lens deviates this second ray by making it go through the focal point of the image.

3. Finish drawing this second ray by going through the focal point of the image.

4. Draw the image as it appears on the retina, namely upside down

   Note: The image is located between the intersection point of the two rays and the main axis.



Animations:

http://www.sciences.univ-nantes.fr/sites/genevieve_tulloue/optiqueGeo/lentilles/lentille_mince.html

http://www.proftnj.com/opt-lentimage.htm (In French)