Introduction to Light and Color

Introduction to Light

Light is a form of radiant energy or energy that travels in waves. Since Greek times, scientists have debated the nature of light. Physicists now recognize that light sometimes behaves like waves and, at other times, like particles. When moving from place to place, light acts like a system of waves. In empty space, light has a fixed speed and the wavelength can be measured. In the past 300 years, scientists have improved the way they measure the speed of light, and they have determined that it travels at nearly 299,792 kilometers, or 186,281 miles, per second.

When we talk about light, we usually mean any radiation that we can see. These wavelengths range from about 16/1,000,000 of an inch to 32/1,000,000 of an inch. There are other kinds of radiation such as ultraviolet light and infrared light, but their wavelengths are shorter or longer than the visible light wavelengths.

When light hits some form of matter, it behaves in different ways. When it strikes an opaque object, it makes a shadow, but light does bend around obstacles. The bending of light around edges or around small slits is called diffraction and makes patterns of bands or fringes.

All light can be traced to certain energy sources, like the Sun, an electric bulb, or a match, but most of what hits the eye is reflected light. When light strikes some materials, it is bounced off or reflected. If the material is not opaque, the light goes through it at a slower speed, and it is bent or refracted. Some light is absorbed into the material and changed into other forms of energy, usually heat energy. The light waves make the electrons in the materials vibrate and this kinetic energy or movement energy makes heat. Friction of the moving electrons makes heat.

Introduction to Color

Color is a part of the electromagnetic spectrum and has always existed, but the first explanation of color was provided by Sir Isaac Newton in 1666.

Newton passed a narrow beam of sunlight through a prism located in a dark room. Of course all the visible spectrum (red, orange, yellow, green, blue, indigo, and violet) was displayed on the white screen. People already knew that light passed through a prism would show a rainbow or visible spectrum, but Newton's experiments showed that different colors are bent through different angles. Newton also thought all colors can be found in white light, so he passed the light through a second prism. All the visible colors changed back to white light.

Light is the only source of color. The color of an object is seen because the object merely reflects, absorbs, and transmits one or more colors that make up light. The endless variety of color is caused by the interrelationship of three elements: Light, the source of color; the material and its response to color; and the eye, the perceiver of color.

Colors made by combining blue, yellow, and red light are called additive; and they are formed by adding varying degrees of intensity and amounts of these three colors. These primary colors of light are called cyan (blue-green), yellow, and magenta (blue-red).

Pigment color found in paint, dyes, or ink is formed by pigment molecules present in flowers, trees, and animals. The color is made by absorbing, or subtracting, certain parts of the spectrum and reflecting or transmitting the parts that remain. Each pigment molecule seems to have its own distinct characteristic way of reflecting, absorbing, or transmitting certain wavelengths. Natural and manmade colors all follow the same natural laws.

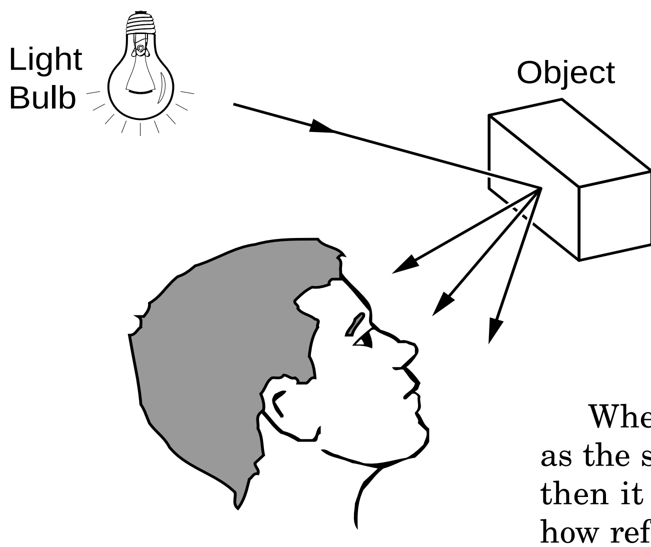
Light, Color, and Their Uses

Introduction to Mirrors and Lenses

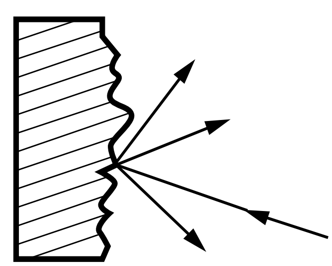
Introduction to Mirrors

As we look around the room, we see most objects by the light that is diffusely reflected from them.

Diffuse reflection of light takes place when the surface of the object is not smooth. The reflected rays from a diffusely reflecting surface leave the surface in many different directions.

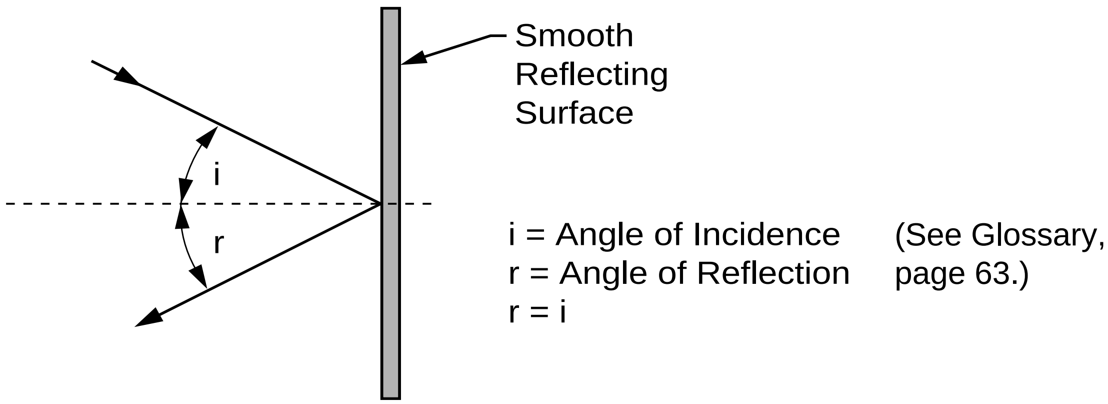


When the surface is smooth, such as the surface of glass or a mirror, then it can be easily demonstrated how reflected rays always obey the law of reflection as illustrated below.



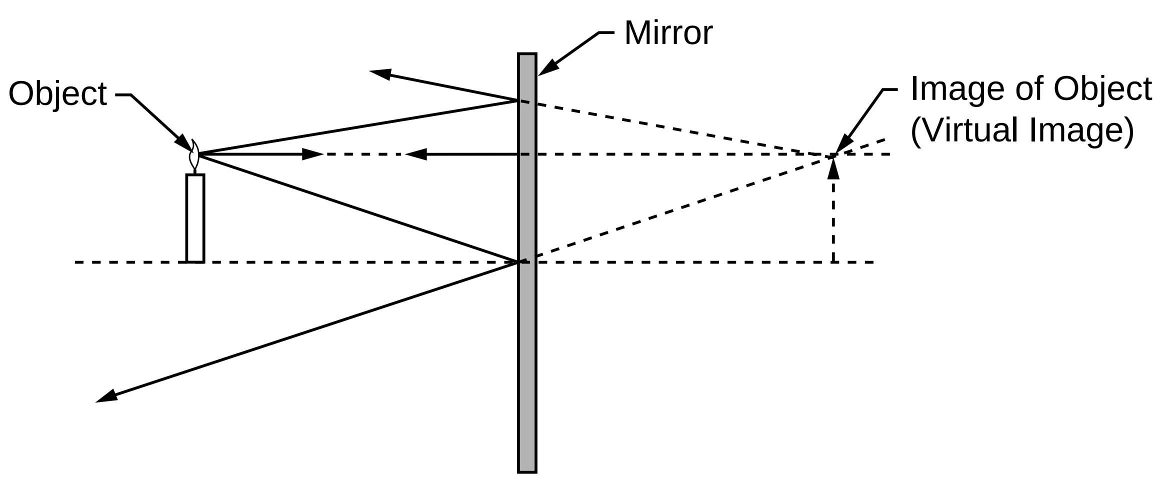
Law of Reflection

The angle of incidence is equal to the angle of reflection.



The Image Formed by Reflection in a Flat Mirror

Every object we see has many rays of light coming from it either by reflection or because it is a light source such as a light bulb, the Sun, a star, etc. Each point on that object is a source of light rays. In the illustration below, the tip of the arrow is used as an example of a point on the object from which rays of light would be coming. As the rays from the object are reflected by the mirror, the reflected rays appear to come from the image located behind the mirror at a distance equal to the object's distance from the mirror. The image is called a virtual image since the rays do not actually pass through or come from the image; they just appear to come from the image as illustrated below.



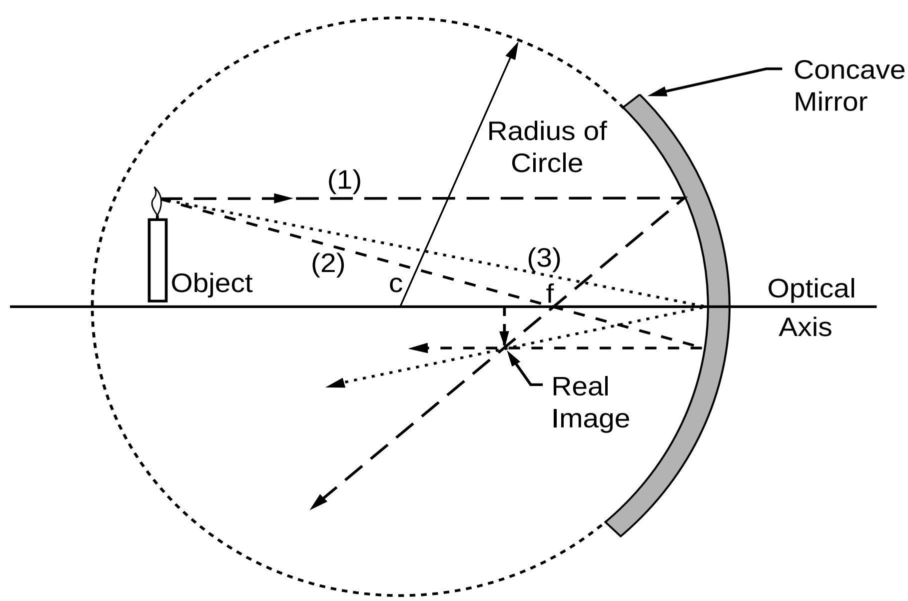
The Image Formed by a Concave Mirror

A concave mirror that is part of a ball or hollow sphere (that is, it has a circular cross section) is a spherical mirror. The focal length is approximately one-half the radius of curvature. A ray that is both parallel and very close to the optical axis will be reflected by the mirror so that it will cross the optical axis at the "paraxial focal point." The paraxial focal point is located a distance of one-half the radius of curvature from the point on the mirror where the optical axis intersects the mirror. The word "paraxial" comes from the Greek "para" or "par" meaning "at the side of, or beside, and axial." Thus paraxial means beside the axis.

Another ray that is parallel to the optical axis, but not close to the axis, will be reflected by the mirror so that it crosses the optical axis, not at the paraxial focus, but a small distance closer to the mirror. This difference in the axis cross-over points is called spherical aberration.

If the mirror has a cross section that is a parabola instead of a circle, all of the rays that are parallel to the optical axis will cross at the same point. Thus, a paraboloidal mirror does not produce spherical aberration. This is why the astronomical telescope known as the Newtonian (invented by Isaac Newton) uses a paraboloidal primary mirror.

For demonstration purposes in the classroom, it works out that we can make the approximation that spherical mirrors behave almost like paraboloidal mirrors and determine that the focal length of a spherical mirror is about one-half the radius of curvature of the mirror.



In the case where the object is located between the focal point and the mirror, such that the object distance is less than the focal length of the mirror, a virtual, upright, and enlarged image is obtained. This is the case when looking at yourself in a concave “make-up” mirror, which is described below.

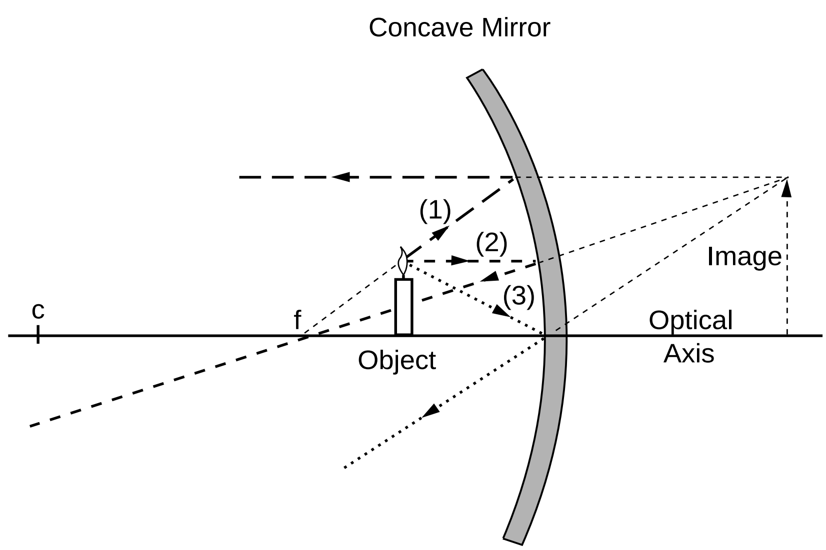
A ray (1) appearing to come from the focal point strikes the mirror and is reflected parallel to the optical axis. A ray (2) parallel to the optical axis is reflected by the mirror so that it goes through the focal point. A ray (3) striking the mirror at the optical axis is reflected so that the angle of reflection is equal to the angle of incidence.

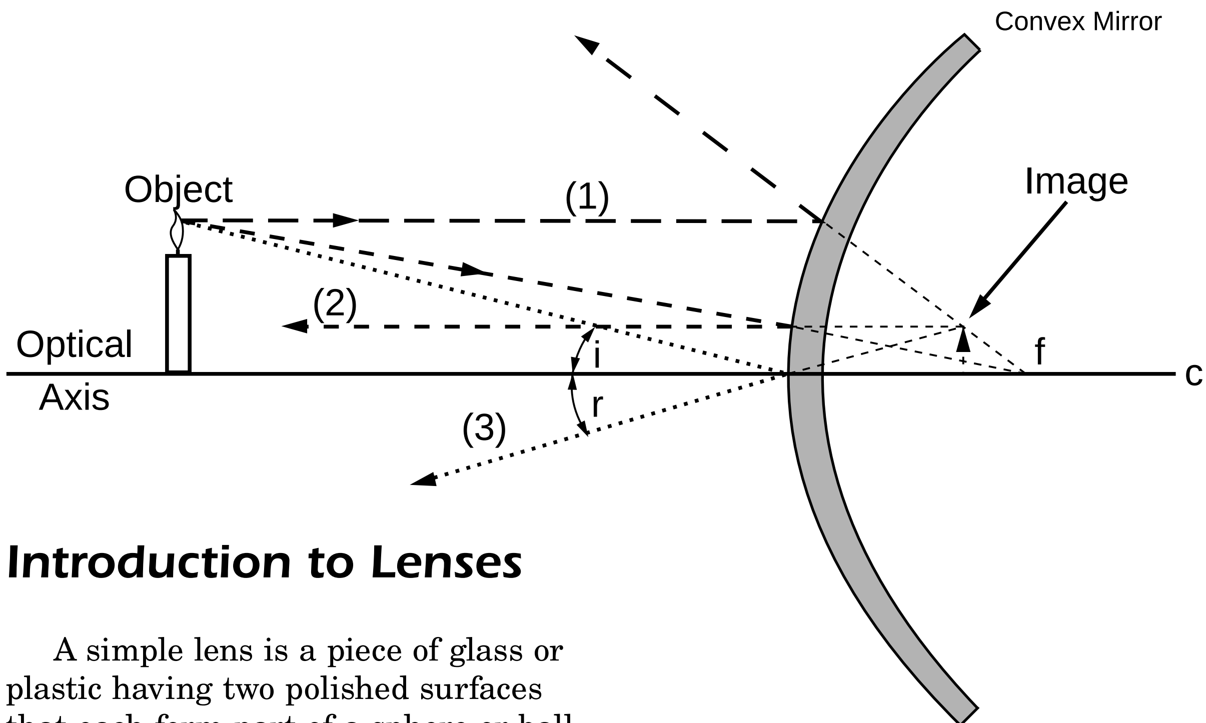
The ray diagram below uses three reflected rays to illustrate how the image can appear to be enlarged and upright. The image formed is a virtual image.

The Image Formed by a Convex Mirror

The image formed by a convex mirror is virtual, upright, and smaller than the object. This is illustrated by the ray diagram on the following page. The diagram depicts the three rays that are discussed in the following paragraph.

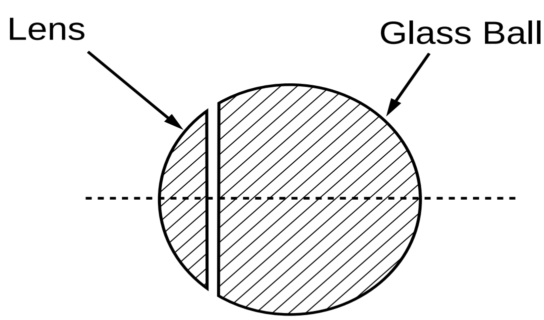
A ray (1) parallel to the optical axis is reflected as if it came from the focal point (f). A ray (2) directed toward the focal point is reflected parallel to the optical axis. A ray (3) striking the mirror at the optical axis is reflected at an angle equal to the angle of incidence.





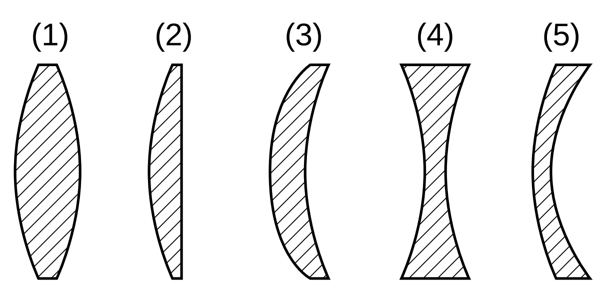
Introduction to Lenses

A simple lens is a piece of glass or plastic having two polished surfaces that each form part of a sphere or ball. One of the surfaces must be curved; the other surface may be curved or flat. An example of a simple lens would be obtained if a piece of a glass ball were sliced off as shown in the following illustration.

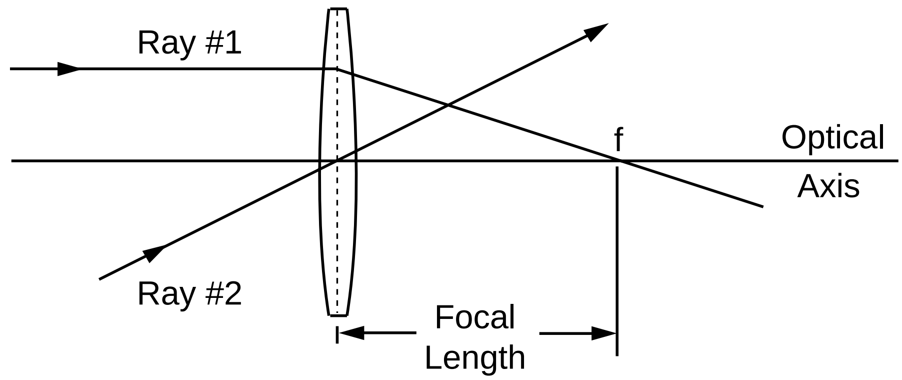


The piece of the ball sliced off would be a lens with a spherical side and a flat side. Lenses can be made in a variety of shapes for various applications. Some examples of lens shapes are illustrated here.

A lens thicker in the center than at the edge is called a converging or positive lens. A lens thinner at the center than at the edge is called a diverging or negative lens. In the illustration shown, lenses 1, 2, and 3 are converging or positive lenses. Lenses 4 and 5 are diverging or negative lenses.



The Image Formed by a Converging Lens



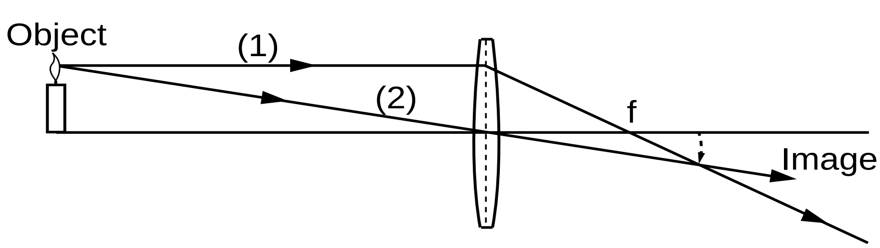
When using a thin lens, that is, the thickness at the center of the lens is not too great, a thin lens mathematical approximation can be used. This approximation assumes the bending of light occurs in one plane inside the lens.

A ray of light coming from a very distant object, such that the ray is parallel to the optical axis, will be bent by refraction at the two surfaces of the lens and will cross the optical axis at the focal point (f) of the lens, as seen in the illustration below. A ray passing through the center of the lens will pass through the lens undeviated.

The size and location of an image formed by a lens can be found by using the information from these two rays which is shown in the illustration below.

The following illustration depicts two rays, which are defined in the following text. A ray (1) parallel to the optical axis passes through the focal point (f). A ray (2) passing through the center of the lens is undeviated.

The image is real, smaller than the object, and upside down. If a piece of paper is placed at the image location, a real image can be seen on the paper. An example of this is taking a picture with a camera, where the photographic film is located at the image position.



Light, Color, and Their Uses

A Simple Magnifier

When the object lies between the lens and the focal point, a virtual, upright, and enlarged image is obtained, as seen in the illustration below.

Three rays are included in the illustration. Following are descriptions of these rays. A ray (1) leaving the object parallel to the optical axis will bend at the lens and go through the focal point (f). A ray (2) leaving the object going through the center of the lens will be undeviated. A ray (3) leaving the object as if it came from the front focal point of the lens will bend at the lens and travel in a line parallel to the optical axis.

After passing through the lens, the three rays described above will appear to come from an enlarged and upright image. Any other ray leaving the tip of the object will appear to come from the tip of the image after passing through the lens. The three rays used in the illustration below were chosen because their paths are always known. Two rays are actually enough to locate the image, while the third ray is used for an additional check of the location of the image.