National Academy of Opticianry

Continuing Education Course

Approved by the American Board of Opticianry

Mirrors

National Academy of Opticianry
8401 Corporate Drive #605
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National Academy of Opticianry

PREFACE:

This continuing education course was prepared under the auspices of the National Academy of Opticianry and is designed to be convenient, cost effective and practical for the Optician.

The skills and knowledge required to practice the profession of Opticianry will continue to change in the future as advances in technology are applied to the eye care specialty. Higher rates of obsolescence will result in an increased tempo of change as well as knowledge to meet these changes. The National Academy of Opticianry recognizes the need to provide a Continuing Education Program for all Opticians. This course has been developed as a part of the overall program to enable Opticians to develop and improve their technical knowledge and skills in their chosen profession.

The National Academy of Opticianry

INSTRUCTIONS:

Read and study the material. After you feel that you understand the material thoroughly, take the test following the instructions given at the beginning of the test. Upon completion of the test, mail the answer sheet to the National Academy of Opticianry, 8401 Corporate Drive, Suite 605, Landover, Maryland 20785 or fax it to 301-577-3880. Be sure you complete the ABO – NCLE evaluation form on the answer sheet. Please allow two weeks for scoring and test results.

CREDITS:

The American Board of Opticianry has approved this course for One (1) Continuing Education Credit toward certification renewal. To earn this credit, you must achieve a grade of 80% or higher on the test. The Academy will notify all test takers of their score and mail the credit certificate to those who pass. You must mail the appropriate section of the credit certificate to the ABO and/or your state licensing board to renew your certification/licensure. One portion is to be retained for your records.

AUTHOR:

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INTENDED AUDIENCE:

This course is intended for opticians of all levels.

COURSE DESCRIPTION

This course will present information regarding mirrors. It will continue with information regarding the laws of reflection. Information included here will be what mirrors are and types of mirrors.

LEARNING OBJECTIVES/OUTCOME

At the completion of this section, the student should be able to:

- discuss the differences between first surface mirrors and second surface mirrors,
- explain how convex mirrors and concave mirrors are similar to lenses and how they differ,
- identify how specular reflection and diffuse reflection differ, and
- diagram the ray paths of mirrors.

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Mirrors

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Mirrors

The law of reflection states: the angle of incidence is equal to the angle of reflection. In addition, unless interrupted, a single ray of light travels in a straight line.

A mirror is an object with a surface that has good specular reflection; that is, it is smooth enough to form an image. The most familiar type of mirror is the plane mirror which has a flat surface. Curved mirrors are also used to produce magnified or diminished images or focus light or simply distort the reflected image.

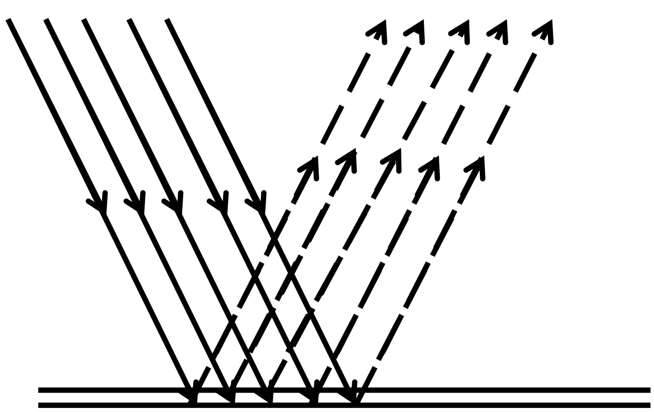
Mirrors are commonly used for personal grooming (in which case the old-fashioned term looking-glass can apply), decoration, and architecture. Mirrors are also used in scientific apparatus such as telescopes, lasers, cameras, and industrial machinery.

Most mirrors are designed for visible light. However, mirrors designed for other types of waves or other wavelengths of electromagnetic radiation are also used, especially in optical instruments.

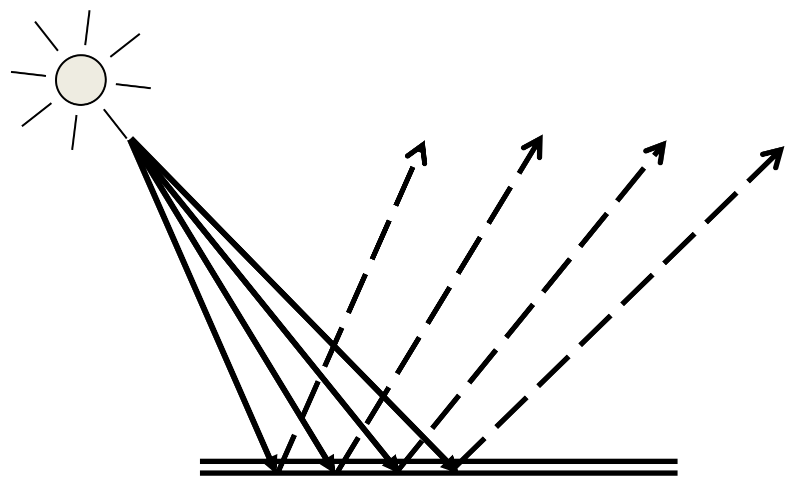
We are going to look at three types of mirrors: plane, concave and convex.

If light strikes a reflective object, the ray of light bounces back at a predictable angle based on the law of reflection. If it strikes a surface at a perpendicular line, it is reflected back on itself. A light ray which is reflected from a surface will be reflected in the plane formed by the normal *(that perpendicular line to the mirror)* to the surface and the incident ray. It will be reflected on the opposite side of the normal as the incident ray, and the angle it forms with the normal will be equal to that formed by the incident ray.

A beam of light uses the same principle of reflection as a ray of light. It acts in the same way as a single ray of light when it is reflected.



When a pencil of light (a group of rays diverging from a single point on a source) strikes the surface of a mirror, the rays will continue to diverge after reflection.

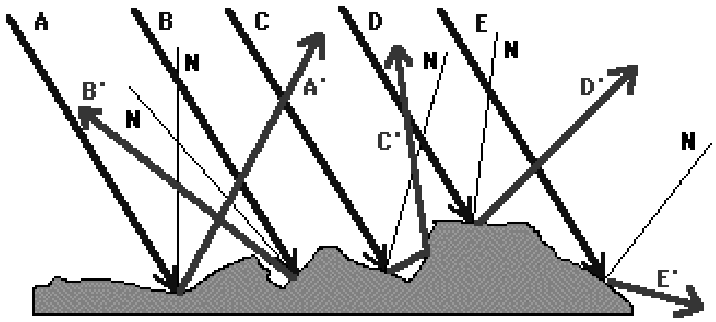


Diffused Reflection

If light falls on a surface with irregularities or is opaque, light will still be reflected back but it will do so in a random manner, not creating a perfect reflection. In accordance with the law of reflection, the light will reflect off the surface in a very predictable manner. A normal can be drawn at every point of incidence. Once done, the angle of incidence is determined and the angle of the reflection can be determined. It will be exactly the same angle from the normal and the incident angle. The light ray will be reflected in such a manner that the angle of incidence is equal to the angle of reflection. This predictability concerning the reflection of light is applicable to the reflection of light off all level surfaces whether they are horizontal surfaces, vertical surfaces, angled surfaces, or even curved surfaces.

Think of a reflection in a clear pool of water. If there are little or no surface waves, the reflection is a good representation of the original. However, if there are waves in the water, the image will be there but will be distorted. So the law of reflection will be satisfied, but the irregularities in the surface will keep the rays from forming a clear image. The reflection is diffused.

As long as the normal (perpendicular line to the surface) can be drawn at the point of incidence, the angle of incidence can be measured and the direction of the reflected ray can be determined. Looking at the following diagram, a series of incident rays and their corresponding reflected rays demonstrates how rays strike a surface with a different orientation; yet each ray reflects in accordance with the law of reflection.



Specular Reflection

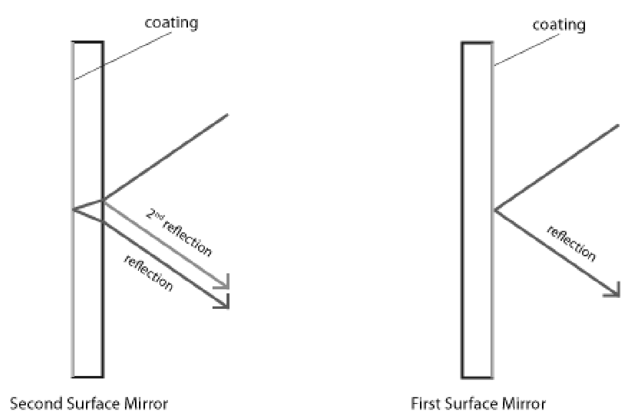
However, if the surface is smooth or polished, the reflection is referred to as specular reflection. This is when the rays of light reflecting back are predictable and non-random. In addition, the smooth/polished surface must have irregularities that are considerably smaller than the wavelength of the light falling on it in order to result in specular reflection and image formation.

There could be a number of interesting comparisons between specular reflection and diffuse reflection. Think of driving at night. If you are driving on a dry asphalt roadway, although the visible light is diminished, because of the irregularity of the asphalt, you are generally not bothered by reflections. However, consider when it has been raining. Then the asphalt is wet. What happens is that the irregular surface is filled in with the water and it becomes smoother causing reflections. When the asphalt is dry, the surface is irregular (rough) and it produces diffuse reflections, which are not as bothersome, but when it is wet, it produces specular reflections which can have significant glare due to the reflections. 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.

From this point forward, we will be discussing specular reflection.

Types of Mirrors

During this section, we will discuss the different types of mirrors.



First of all, let's discuss first surface mirrors (front surface mirrors) and second surface mirrors (back surface mirrors). Each type of mirror has advantages and disadvantages. While front surface mirrors may produce a clearer image, it may be more easily damaged to front surface abrasions, etc. In addition, because of the method of production, the cost is usually higher than second surface mirrors. Because of the protective glass or acrylic on the front of a second surface mirror, the reflective surface/coating is protected, but it produces a ghost image.

First surface mirrors

First surface mirrors are made for applications requiring a strict reflection without a ghosting effect as seen with a second surface mirror - where a faint secondary reflection could be observed coming from the front surface of the glass. This includes most optical applications where light is being manipulated in a specific manner. Telescopes, projection televisions, and periscopes use this type of mirror. A first (or front) surface mirror does not allow for the process of multiple reflections and ghost images which occur in a second (or back) surface mirror simply because the front surface mirror does not have the protective glass surface which is the cause of multiple reflections that reduce the quality of the image. Therefore, a front surface mirror produces an image that is almost always reflected at full intensity and brightness which creates a higher quality image.

Second surface mirrors

Most mirrors that we use daily are referred to as second (or back) surface mirrors. They are constructed of protective clear glass or acrylic over a silvered coating on the back surface. While the front is not silvered, it will have a weak reflection, usually about 4%. The back surface which IS silvered will produce a strong reflection. The strong reflected image only reflects off the mirror surface once and then exits through the glass. However, the reflection from the reflective surface forms a second image which is also known as a ghost image and is slightly shifted from the main image. A third image or second ghost image is formed as a result of the light from the main image which reflects back to the mirror surface from the glass which is covering the mirrored layer.

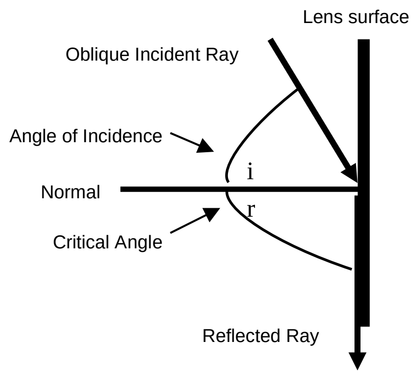
You may test to see if a mirror is a first surface mirror or a second surface mirror by simply placing your finger on the mirror. If your finger appears to be touching the reflection, it is a first surface mirror. However, if there is a space between your finger and the reflection, it is a second surface mirror.

Total internal reflection (through prism)

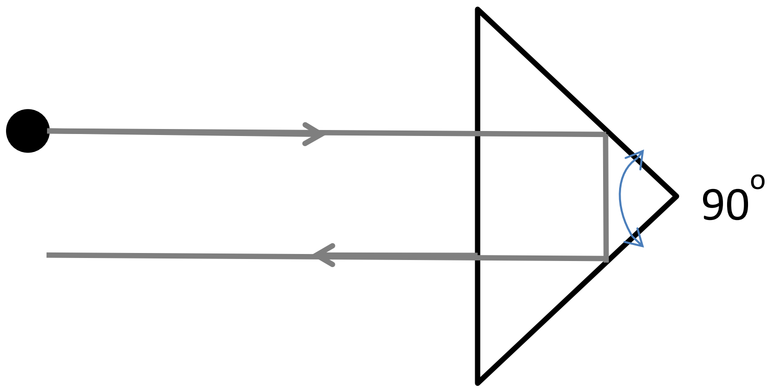
In optics, the critical angle is the angle of incidence above which total internal reflection occurs. In other words, it is defined as the angle of incidence which provides the angle of refraction of 90 degrees, which means that the ray of light is traveling along the surface of the medium (lens). When the critical angle is exceeded, total internal reflection will occur. This refers to light rays striking the refracting medium at an oblique angle. This is one of the reasons that anti-reflective coatings are placed on lenses, especially high index lenses. Critical angle is usually defined as 42 degrees.

Have you ever been swimming just underwater when the water is very calm and looked at the water's surface? The underneath surface of the water appears mirror-like.

Total internal reflection is what gives a critically cut diamond maximum sparkle.



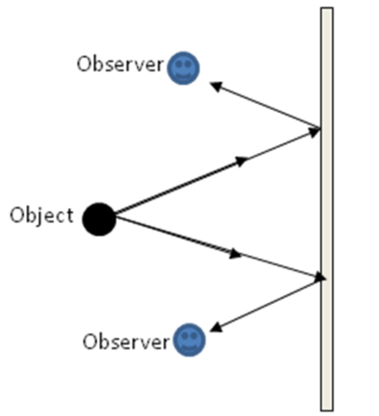
A prism with an angle of 90º at its apex will change the direction of a ray of light and produce a mirror image without introducing chromatic aberration, using total internal reflection. It eliminates front surface reflections.



Plane Mirrors

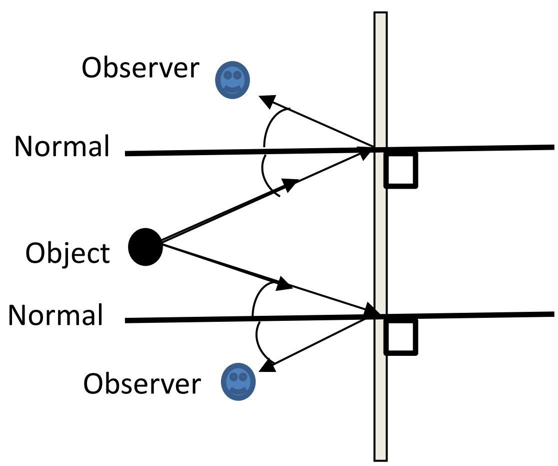
Plane mirrors are mirrors that are flat. They have a smooth, flat (plano) surface. If parallel rays of light fall on a plane surface, the rays will be reflected. As demonstrated previously, that means that if incident rays are parallel, they will remain parallel, and if they are converging or diverging rays, they will continue to converge or diverge at the original angle to each other. Some objects behave like mirrors including smooth surfaces of lakes and ponds, windows, sides of aquariums, etc.

When an object is placed in front of a mirror, two different observers appear to see an image of the object in different places. The light, however, travels from the single object to the mirror and then to the respective observers.



Plane Mirror

The manner in which it reflects must meet the conditions stated previously. In other words, the angle of reflection will equal the angle of incidence. Notice how the light reflects from the smooth surface of the mirror, creating congruent or equal angles to the normal at each place it strikes the mirror. The two observers only see light when it has been reflected by the mirror in the proper manner.



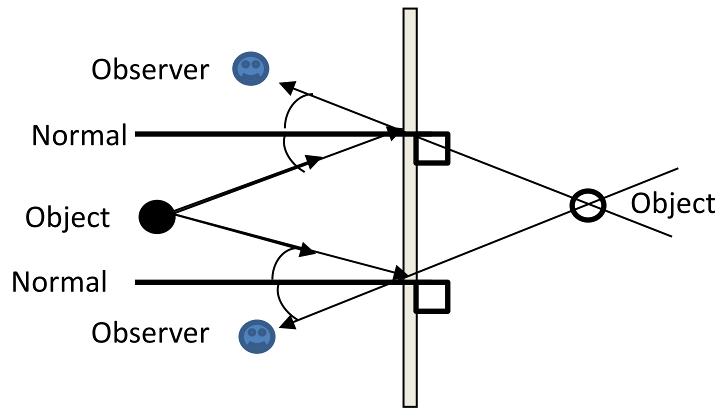
Plane Mirror

Rays will emerge from the reflecting surface at the same angle with respect to each other. Therefore, the image appears to be the same distance behind the surface as the object is in front of it. This is the same as saying that the reflecting surface did not change the vergence of the rays.

For that reason, the apparent distance of the image to the observer did not change. The lack of change in vergence also results in the image appearing to be the same size as the object. Our brains use the law of rectilinear propagation (light travels in a straight line) to determine how far away an object is. The brain interprets the image to be where the rays would be coming from if they had traveled in a straight line to get to the eye. So we interpret the object to be where the image is, behind the mirror, even though intellectually we know none of the light entering our eye actually came from there.

The observers' lines of sight can be extended back behind the mirror, to a place where the light rays both seem to originate. They would agree upon this one location, regardless of where they are standing. This is, therefore, the location of the image.

However, the observer will see an image which is not on the surface itself. Instead, the observer will see images of the objects which are on the same side of the surface as the observer. The images will appear to be erect, will be reversed side-for-side, and will appear to be the same distance behind the surface as the object is in front of the surface.



Plane Mirror

What is the nature of the light at the image location? In fact, there is no light there. This is only the apparent source of the light so it is referred to as a *virtual image*. Virtual images are ones that are not formed by putting the light rays together, but only appear to exist as the apparent source of the light rays.

Curved Mirrors

You may not think that you see curved mirrors much in everyday life, but in reality, you probably do. Have you ever seen this? "**WARNING: OBJECTS IN MIRROR MAY BE CLOSER THAN THEY APPEAR".** Side mirrors on automobiles make images smaller and appear further away. The purpose of that??? To allow the driver to have a wider/higher observation field.

Another example is makeup mirrors. They are used to magnify images. In addition, we've all seen the mirrors used for security purposes that, allow the observer to see around blind corners. These are all curved mirrors. In effect, they are, in fact, very similar to lenses. However, for the mirrors to follow these rules, they have to be evenly shaped, and therefore are usually made of the surface of a sphere shape, though they can also be parabolic. The mirror is given a name depending on whether it is the inside surface or the outside surface of the sphere that reflects.

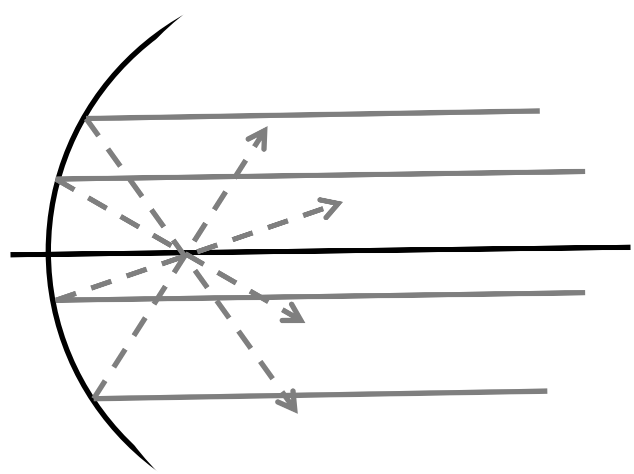
A curved surface may be either concave (center bulging away from the observer) or convex (center bulging toward the observer.) We will be concerned only with curved surfaces which are spherical in nature (described by a circle or sphere).

Convex mirrors are known as diverging mirrors, while concave mirrors cause parallel light rays to converge. This is opposite of ophthalmic lenses. The name of the mirror indicates the side of the sphere that is reflective.

In a concave lens, the point at which parallel light rays converge is (once again) called the focal point, sometimes known as the principal focus. From the law of reflection, where the angle of incidence must equal the angle of reflection, and the above idea, we know that:

- A ray that is parallel to the principal axis will be reflected so that it passes through the focal point, and conversely.
- A ray that passes through the focal point will be reflected so that it is parallel to the principal axis.

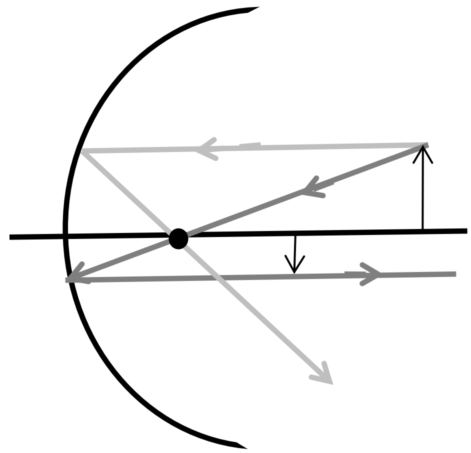
The focal point and the center of the would-be sphere of which the mirror was a part, lie on a line that is also called the principal axis, as in lens diagrams below.



In addition, in the above diagram, the principal axis (the focal point) is not very close to the center of the sphere.

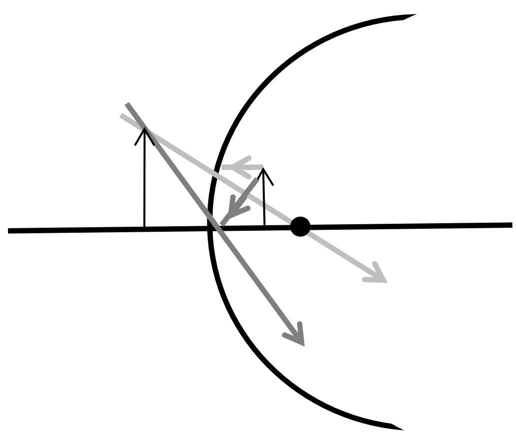
A surface which is spherical in nature will have a center of curvature. This is the point that is equidistant from all points on the surface of the sphere. We will suppose that the surface is mirrored, or reflects all incident light.

Ray diagrams can be drawn, to show how curved mirrors produce images. In order to be able to construct the image of a point, you will only need two rays. If the focal point is known, you can construct two rays and their reflections without having to measure any angles. The diagram below demonstrates a ray that is parallel to the principal axis and a ray that goes through the focal point.

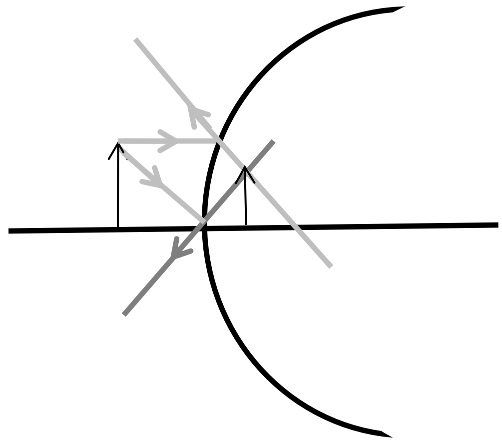


In the figure above, a concave mirror is used to make a real, inverted image of the thin vertical arrow (symbolizing the object). Notice that in the case of mirrors, real images are located on the same side of the mirror as the object. A concave mirror can be used to make an enlarged or diminished real image of an object just as a convex lens can. This is because, after all, the rays in a mirror diagram can go both ways, and for real images, the object and the image can be interchanged.

A concave mirror is used to make an upright, magnified, virtual image. Once again it acts in the same way as a convex lens. In this case, however, it was necessary to measure one angle, because drawing a ray through the focal point would not have been of much use. Also, because the reflected rays diverge, they are followed back to their apparent origin, the image of the tip of the thin vertical arrow. This is another indication that the image produced is virtual. A concave mirror set up is often used in telescopes and is also used for shaving or applying makeup.



The ray diagram on the curved mirror below shows how a convex mirror creates an upright, diminished, virtual image, just as a concave lens can do. This diagram is similar to the one just demonstrated, only with the image and the object switched. This diagram, however, does not require that the focal point is known, though it does require two angles to be measured.



Because spherical mirrors are so similar to lenses, it is easy to expect that spherical mirrors also follow the lens equation. As a matter of fact, they do. The difference is what is considered by convention to be real or virtual. A simple guideline for this is that if the item (e.g. focal point, image distance) in question is on the same side of the mirror as the object, it is considered to be real. Otherwise, it is virtual, and its value in the lens equation is said to be negative.

Finally, convex mirrors produce smaller images, so the image may appear further away. The kind of mirror used in the rear-view mirror must, therefore, be a convex lens. On the other hand, concave mirrors produce images which are larger than they actually are, which makes them so useful as makeup mirrors.

Conclusion

As you can see, mirrors are not just for grooming. They have a plethora of uses. Understanding the principles of optics including the principles of reflection will make you a better optician/technician.

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