

Light and Optics Study Notes

Properties of Light

- Light travels in a straight line.
- Light can be reflected.
- Light can change direction.
- Light is a form of energy.
- Light travels very fast.

Optical Devices

An optical device is any technology that uses light. Some examples include: eye glasses, microscopes, telescopes, binoculars.

Microscopes

A microscope allows you to see things that cannot be seen with the naked eye. It combines the power of at least two different lenses: **the eye piece and the objective lens**. The invention of the microscope has opened up our understanding of a world of microorganisms that affects our lives significantly.

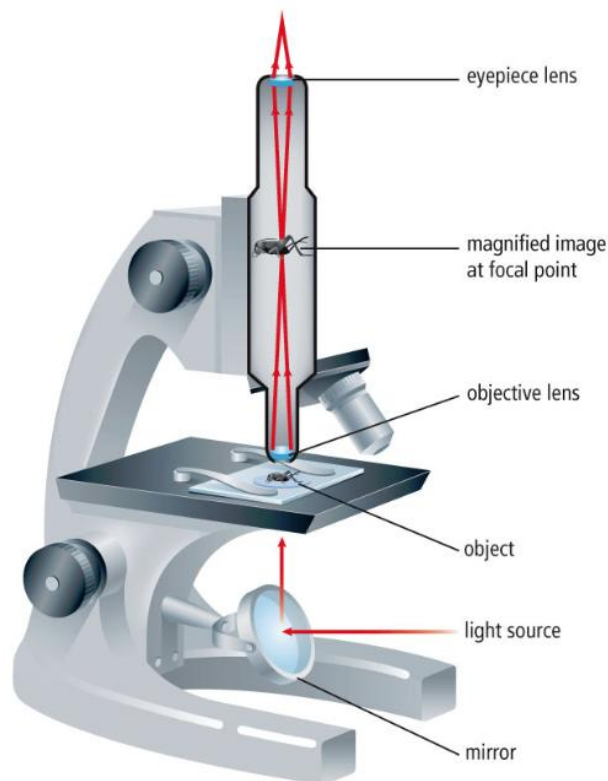
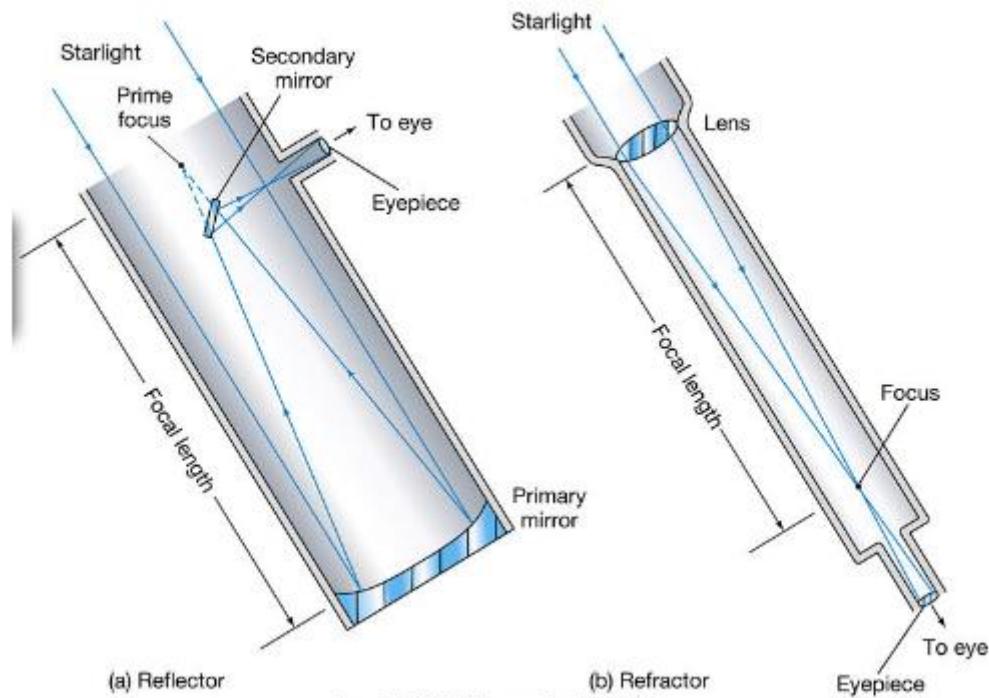


Figure 6.14 This microscope uses two convex lenses to magnify small objects. To focus the image, you have to move the object you are studying closer to or farther from the objective lens.

Telescopes

Telescopes work much the same as a microscope. They both **collect and magnify light**. There are two basic types of telescopes: reflecting telescope and refracting telescope.

1. The **refracting telescope** uses a combination of lenses. The larger one gathers light and focuses the rays towards the objective lens.
2. The **reflecting telescope** has a large mirror at one end that gathers light very well and reflects it off another smaller mirror into the objective lens.



Comparing a microscope to a telescope

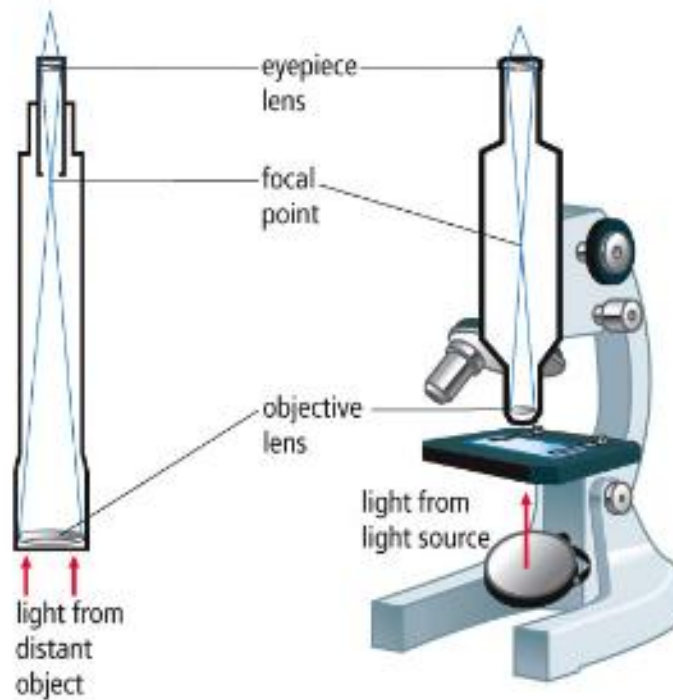


Figure 6.16 In order to focus with a microscope, the object being viewed is moved. In order to focus with a telescope, its eyepiece and the observer are moved.

Other optical devices

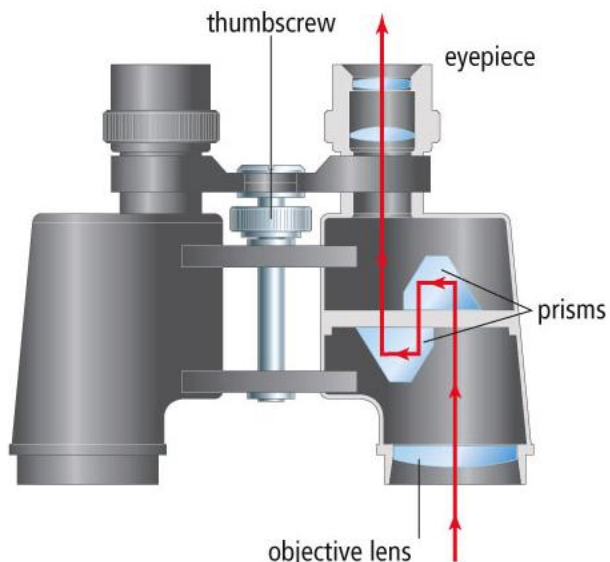


Figure 6.21 The thumbscrew on binoculars is used to change the focal length in order to focus on the objects being viewed.

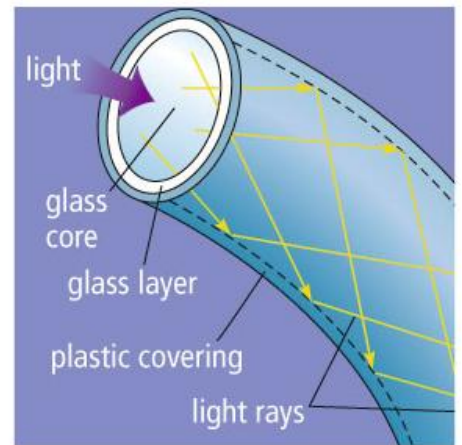


Figure 6.29 Optical fibres make use of total internal reflection.

Light Travels in Rays and Interacts with Material

Ray Diagrams

As light leaves a source it travels in a straight line. Scientists use ray diagrams to show how light travels. Here is a simple ray diagram



Figure 5.2 A ray is an imaginary line showing the direction in which light is travelling.

The farther we move away from the light source the fewer the rays actually reach our eye. That is why light is brighter to us (or more **intense**) when it is close and not as bright (or less **intense**) when we are farther away.

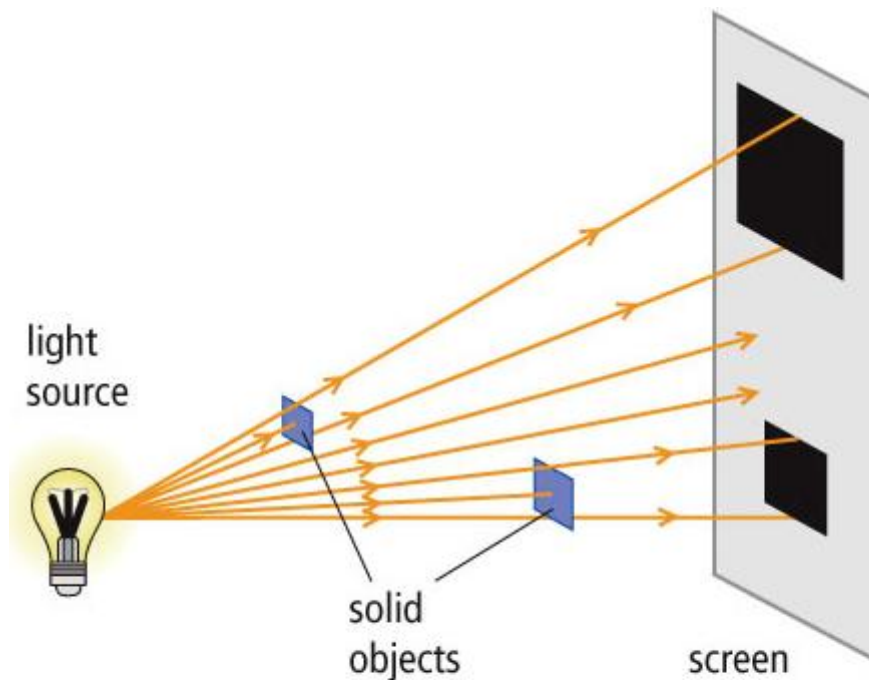


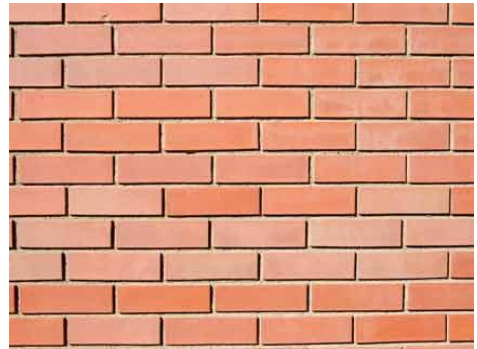
Figure 5.7A A ray diagram shows how the distance from the light source affects the size of the shadow that an object makes. The smaller object casts the larger shadow because it is closer to the light source.

Light Interacts with Different Materials

Transparent- the light will travel right through it; able to see the object on the other side perfectly.

Translucent - some of the light will pass through but not all of it; would be able to see outlines of an object on the other side but not very many details.

Opaque - will not allow any light to pass through it; you cannot see any object through this material.



Luminous – An object that produces light (sun, lamp).

Non-luminous – An object that does not produce light.

How do we actually see things?

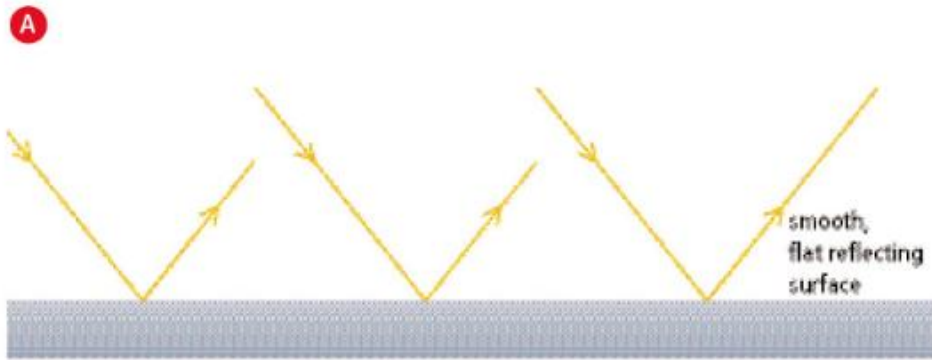
Types of Reflection

1. Regular reflection occurs when light hits a smooth surface.

Regular reflection produces a clear image because the reflected rays remain parallel.

2. Diffuse reflection occurs when light hits an uneven surface.

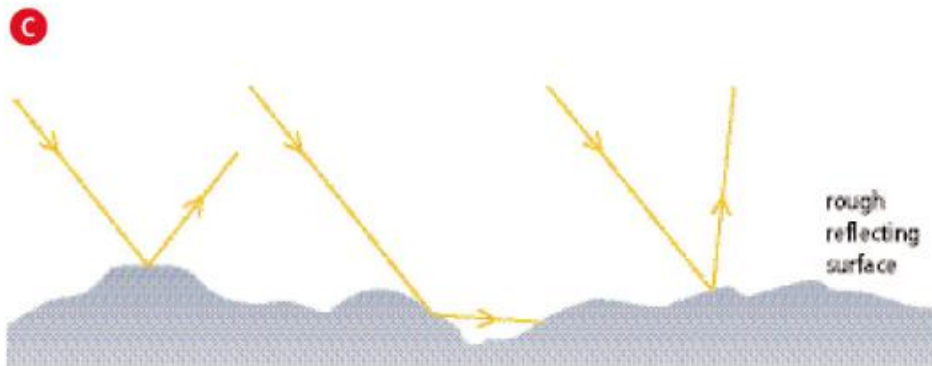
Because the surface is uneven the reflected rays do not remain parallel. The image is not visible.



(A) Smooth surfaces reflect all light uniformly.



(B) Scanning electron micrograph of the surface of paper

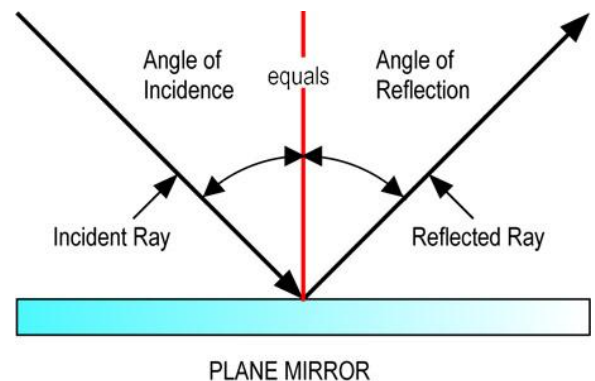


(C) Rough surfaces appear to reflect light randomly.

The Law of Reflection

When an incoming light ray (**incident ray**) bounces off a reflective surface it bounces off at the same angle it comes in at.

According to the **law of reflection**, the angle of incidence equals the angle of reflection.



How a mirror works

A plane mirror reverses an image but it does not change the distance or magnification of the image.

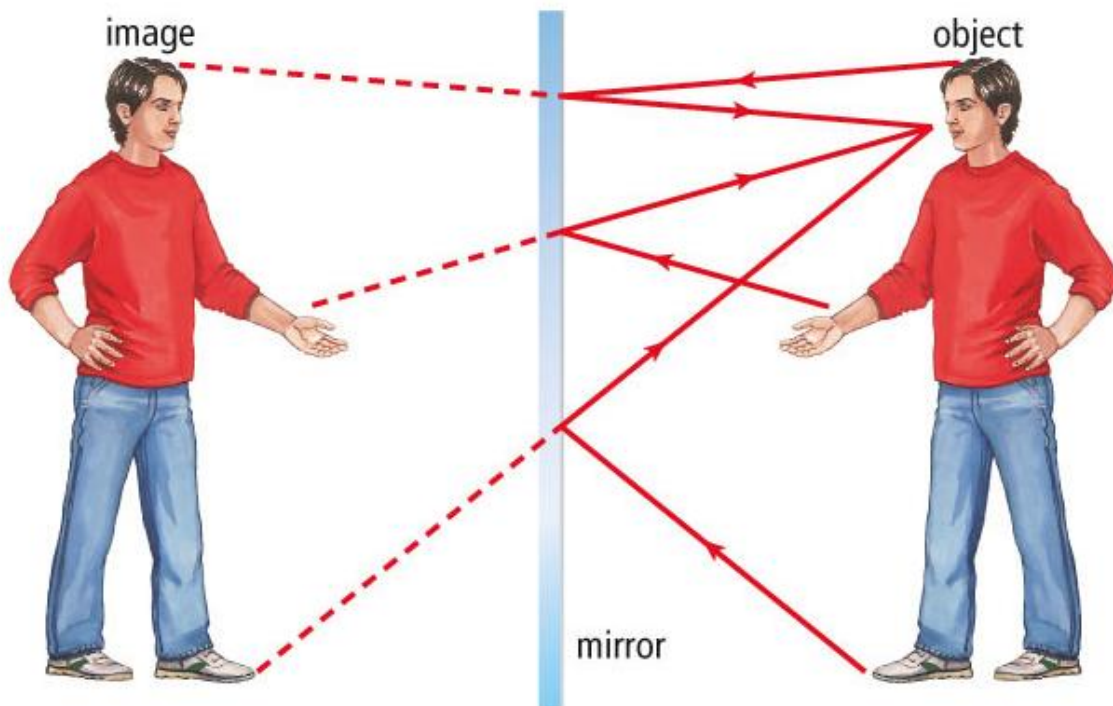


Figure 5.16 When the boy blinks his right eye, the left eye of his image blinks.

Reflecting Light with Curved Mirrors

There are two basic types of curved mirrors: concave and convex.

A **concave** mirror has a surface that curves inward like a satellite dish. These types of mirrors collect light. All of these reflected rays of light will head to a common position called the **focal point**.

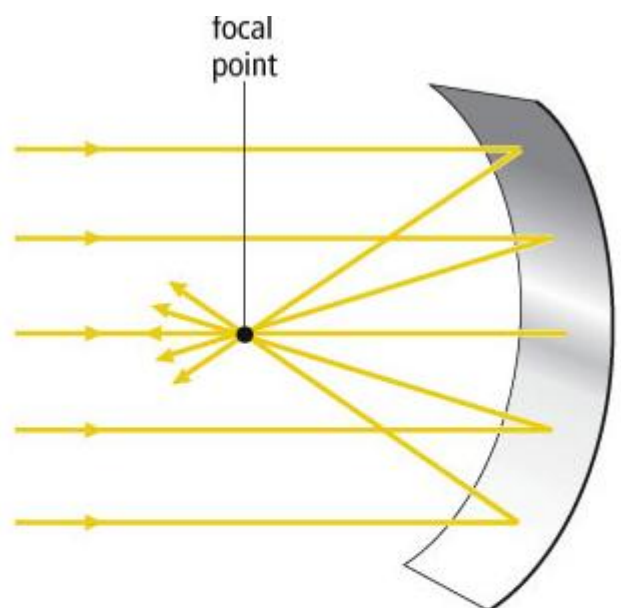
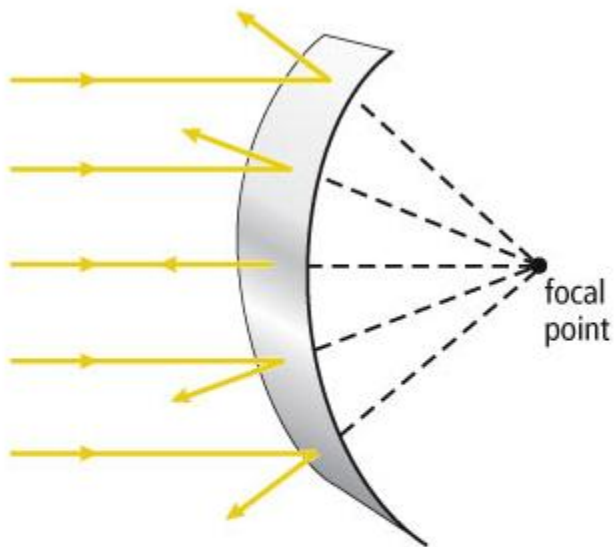


Figure 5.17 Light rays collected by a concave mirror converge on a focal point before spreading out again.



A **convex** mirror has a surface that curves outward. These types of mirrors diverge light. All of these reflected rays of light will not meet.

Figure 5.20 The reflected rays from a convex mirror diverge and do not meet.

Curved mirrors also obey the law of reflection. But because the rays of light are hitting the mirror at slightly different angles (**angle of incidence**), they will reflect at slightly different angles (**angle of reflection**). The distance the object is away from the mirror will affect how the image will look.

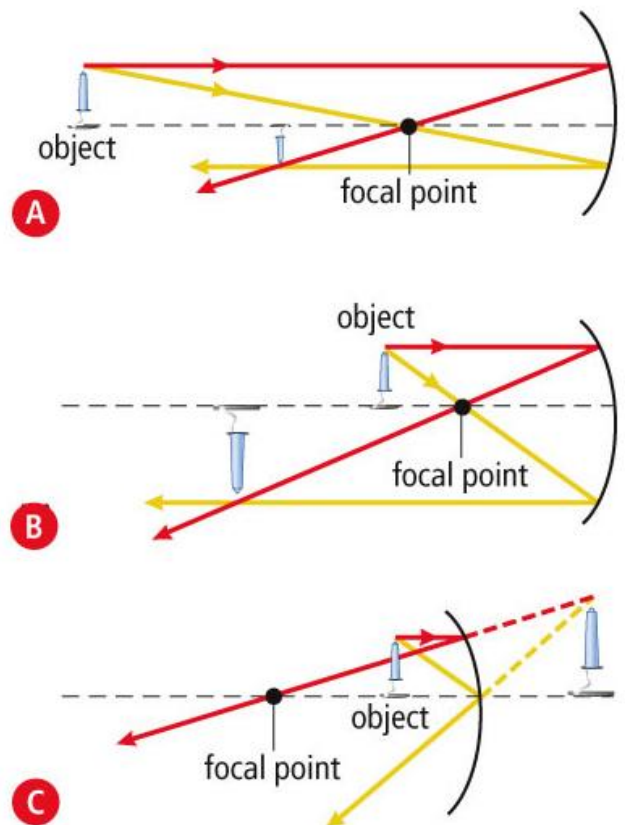
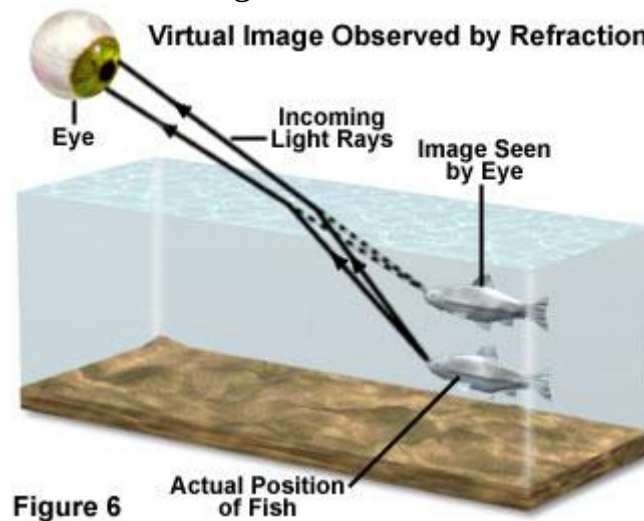


Figure 5.18 The image formed by a concave mirror depends on how far away the object is.

Substances Refract Light

When you look at an object in a medium (lets talk about water for example) we are actually seeing the refracted image not the actual image. **Refraction** is when light bends as it hits a different substance.

For example, trying to catch a fish in a tank of water. This is tricky because the image we are seeing is actually the refracted image of the fish and not the actual fish.



Refraction is due to changes in the speed of light. As light goes through a more dense substance there are more particles to get in the way. This causes the light to slow down. This slowing down is what causes the light to bend or refract.

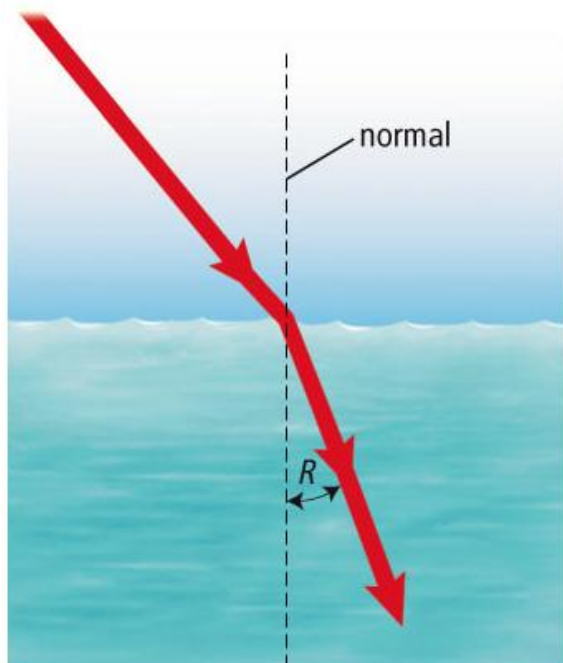


Figure 5.11A When light rays travel from air to water, they slow down and bend toward normal. R is the angle of refraction.

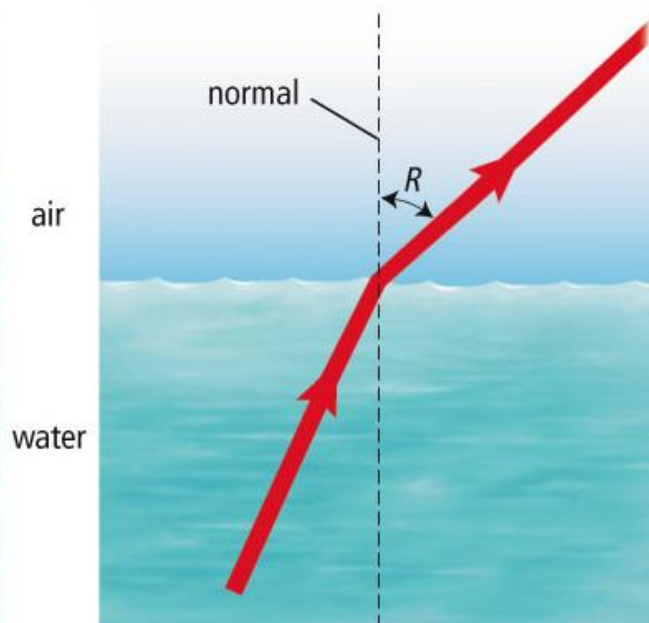
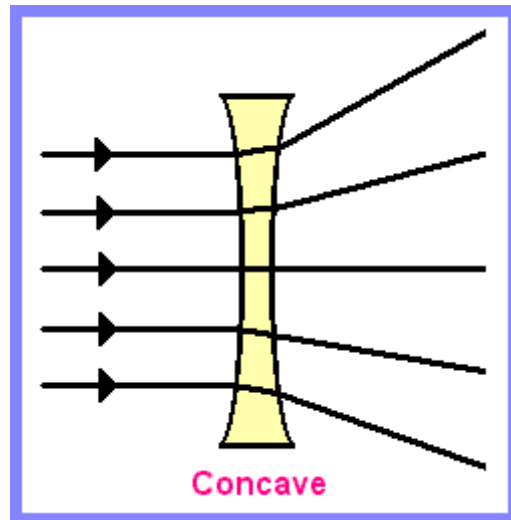


Figure 5.11B When light rays travel from water to air, they speed up and bend away from normal.

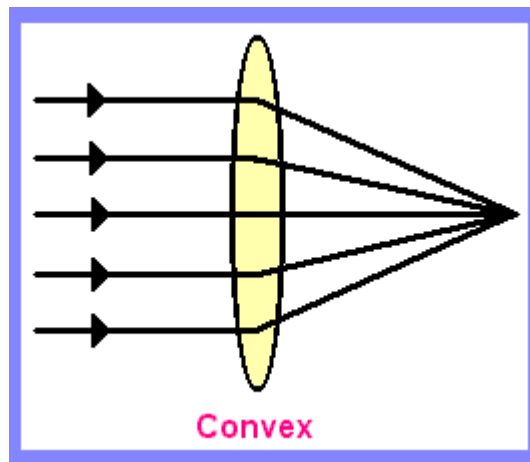
Lenses Refract and Focus Light

A **lens** is a transparent, curved material, like glass. It should be smooth and regularly shaped. Lenses refract light in predictable ways depending on its material, thickness and shape. The most useful lenses are those that form an image when the rays of light are refracted through them.

A **concave lens** is thinner in the center than on the edges. As light passes through this kind of lens it is refracted outwards / they are spread out. These light rays will never meet on the other side of the lens.



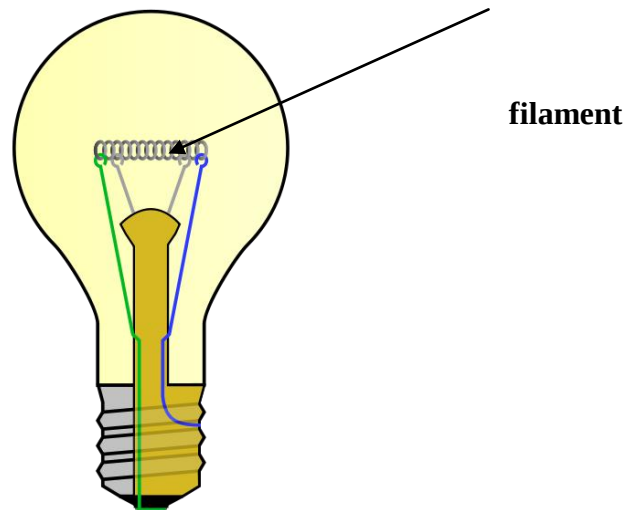
Convex lenses are thicker in the middle than on the outside. As light passes through this kind of lens it is refracted inwards / they move towards one another. These light rays will meet at the focal point on the other side of the lens.



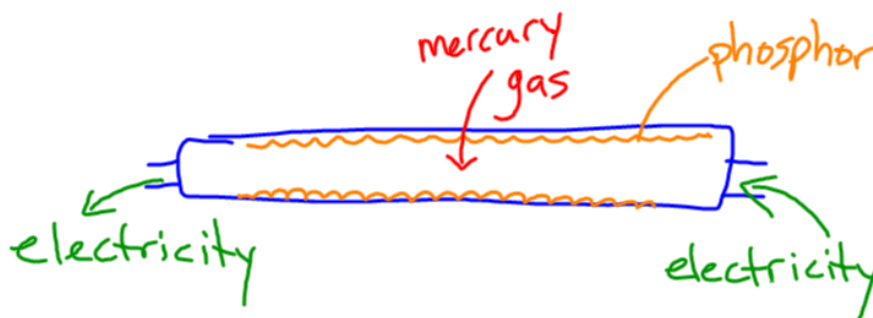
A convex lens is a light collector just like a concave mirror. A refracting microscope uses convex lenses. A convex lens can also form a real image, which can be projected onto a screen. The only consideration to make with a convex lens is that the image that is formed is upside down.

Producing Visible Light

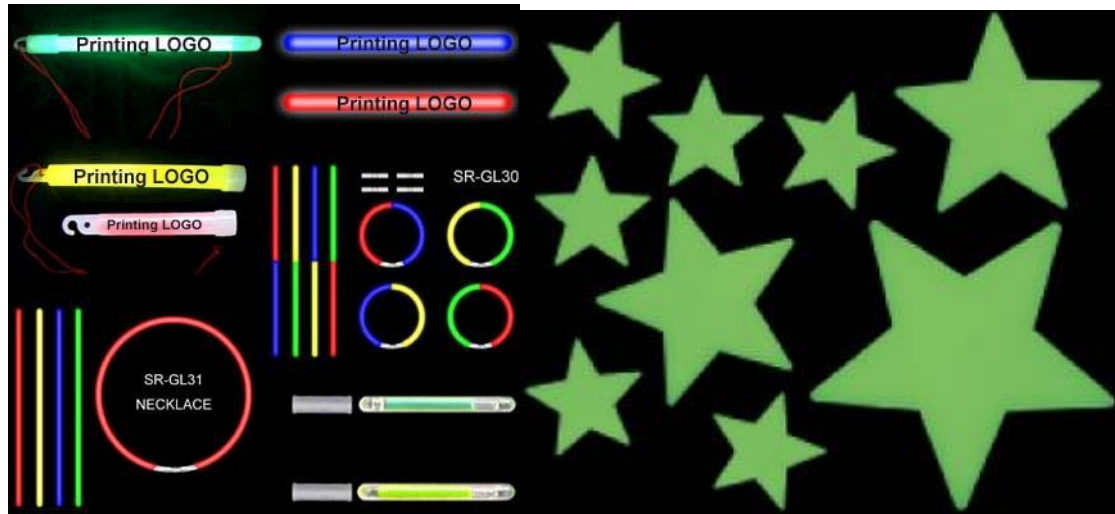
An **incandescent light bulb** is the most common type of artificial light. It consists of a very fine filament in connecting two sides of a circuit. As electricity passes through the filament it lights up instantly. Most of the energy is given off as heat. Only 5% of that energy is actually given off as light. This makes the incandescent light bulb a very inefficient light source but quite a good heat source.



Fluorescent light bulbs work a little differently. Fluorescent bulbs consist of two electrical prongs at both ends, a glass covering, mercury gas to fill the tube and a white powder, called phosphor, that covers the inside of the glass. As **electricity** passes into the tube it energizes the **gas** causing it to give off ultraviolet radiation. The radiation contacts the **phosphor** causing it to glow, giving off **white light**.



Phosphorescent light is similar to fluorescent light. However, the material that is in these lights has the ability to store the radiation. This allows these light sources to produce light long after the source of radiation has stopped. Some examples of these types of light are glow in the dark necklaces and stars.



Bioluminescence is when living things give off light from their bodies. This involves a chemical reaction between materials in the organism's body.



Image Formation in Eyes and Cameras

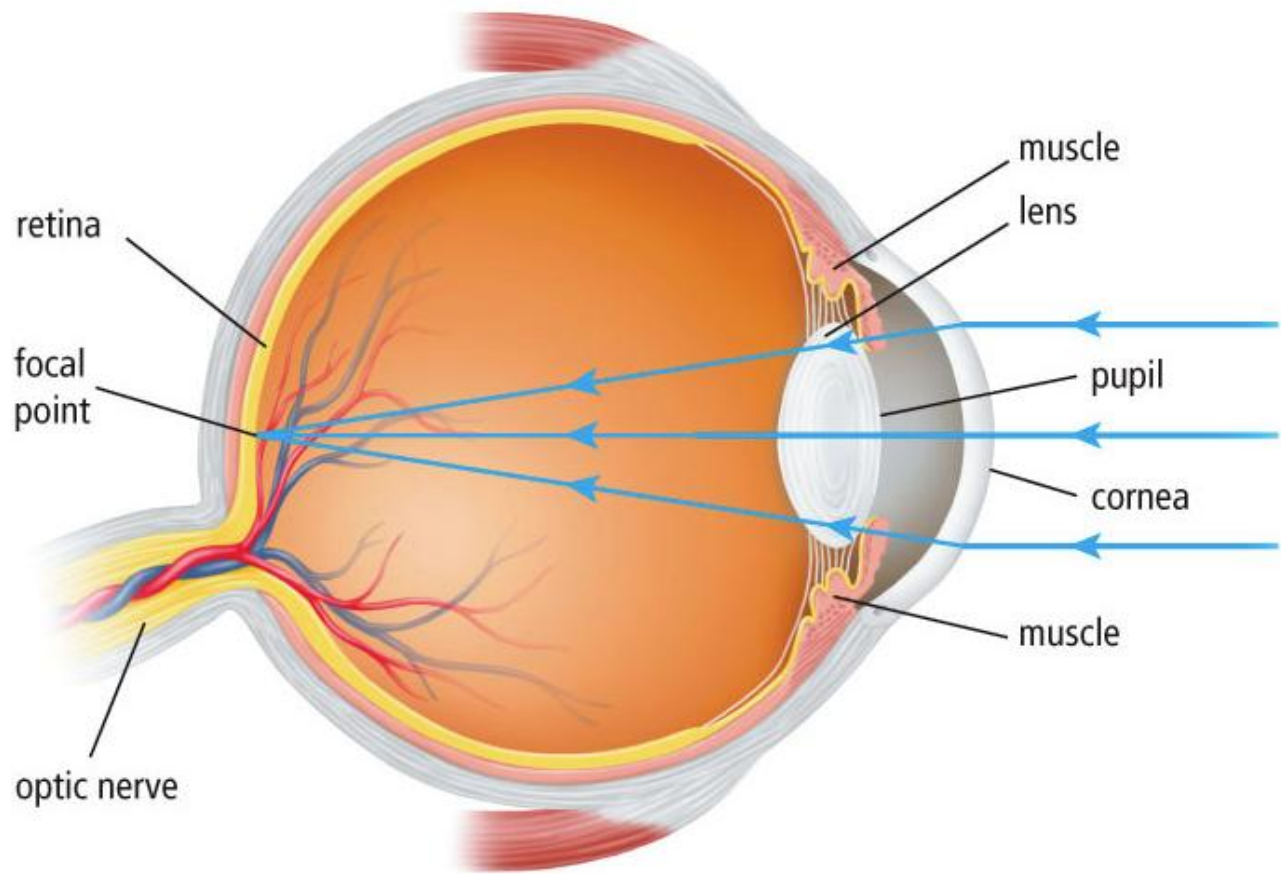


Figure 6.3 The eye in cross section

Light enters the eye through a hole called the **pupil**. The size of the pupil is controlled by the **iris**. This is the part of the eye that is coloured. As the light passes through the pupil it hits the **lens**. The lens refracts the light as necessary and then continues on until it hits the **retina**. The retina is covered with specialized cells called cones and rods. **Cones** are sensitive to colours and **rods** are sensitive to light. These two photoreceptors pass on their messages to the brain through our **optic nerve**. Our brain then interprets these messages as images. **Muscles** attached to the lens of the eye relax or contract to change the shape of the lens. This allows you to focus the object onto the retina of the eye.

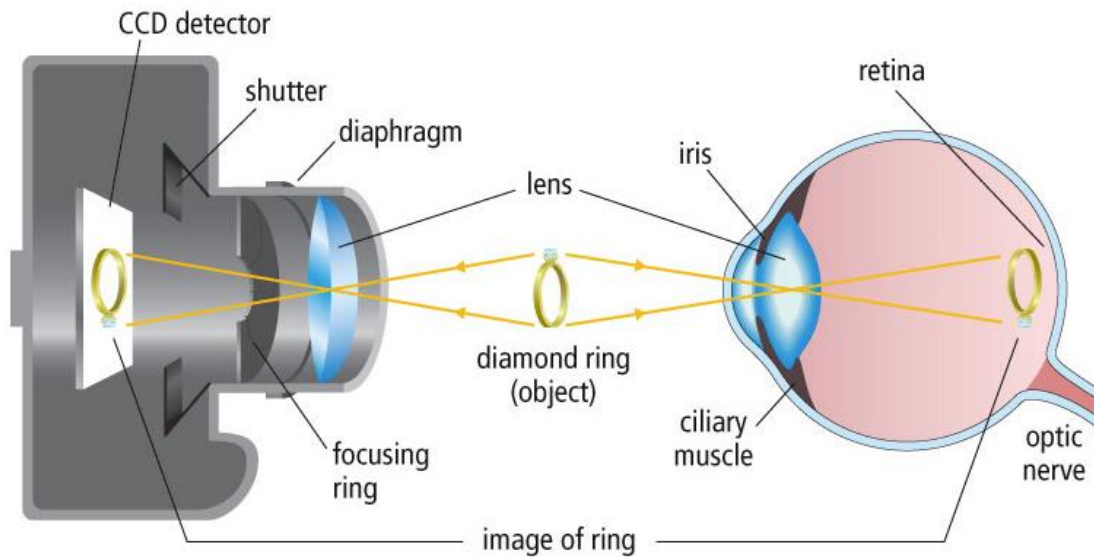


Figure 6.25 A comparison of the camera and the human eye

Cameras work in a similar way. Light passes into the camera through a hole called the **aperture (pupil)**. The size of the aperture is controlled by the **diaphragm (iris)**. The light is also refracted as necessary by the **lens (lens)** of the camera. The light continues on until it hits the **film or CCD detector (retina)**. An image is imprinted onto the film or card which is then turned into actual pictures (**optic nerve to brain**). A camera moves the lens closer or farther away from the object in order to focus the image on the film of the camera.

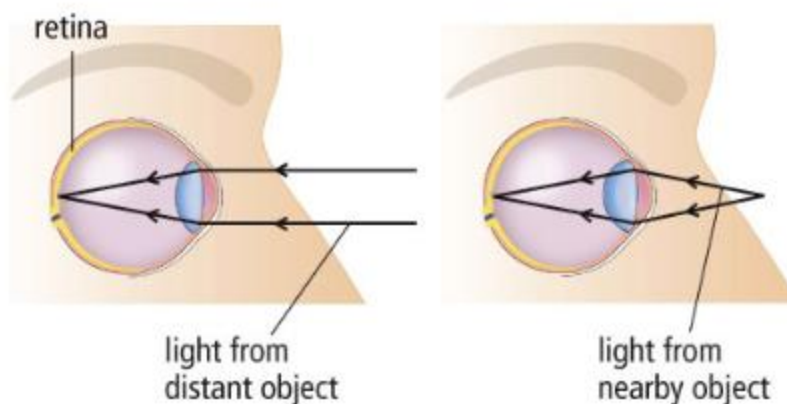


Figure 6.7 How the lens in a normal human eye focusses light rays onto the retina

Nearsightedness

When a person is nearsighted the focal point of the image occurs **before the retina**.

Therefore the image will not be focused. To correct this problem people often are fitted with **concave** lenses.

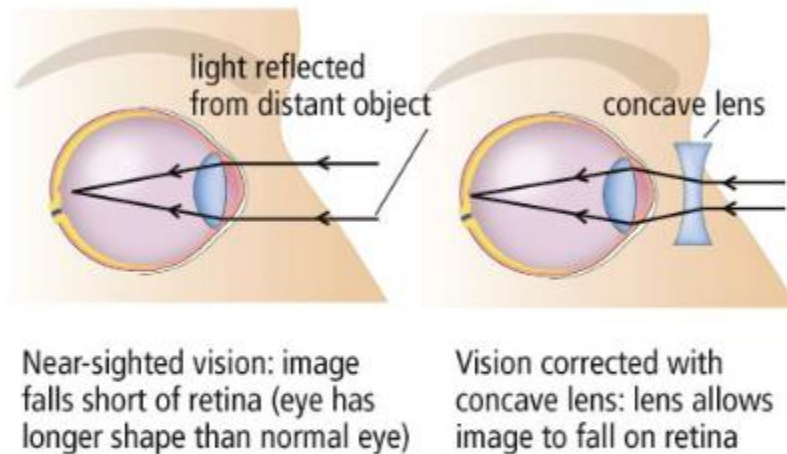


Figure 6.8 How a concave lens in eyeglasses corrects near-sightedness

Farsightedness

When a person is farsighted the focal point of the image occurs **after the retina**. Therefore the image will not be focused. To correct this problem people often are fitted with **convex** lenses.

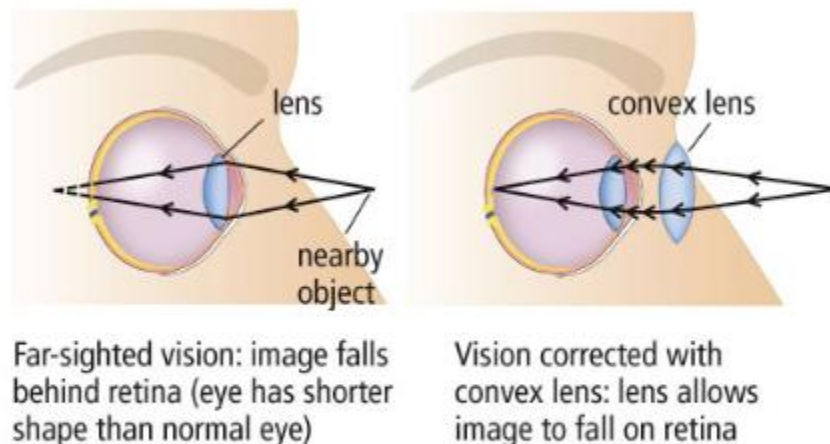


Figure 6.9 How a convex lens in eyeglasses corrects far-sightedness

Other Eyes in the Animal Kingdom

Two types of eyes are Camera Eyes and Compound Eyes.

Camera Eyes

These types of eyes consist mainly of a cornea, lens, retina and are generally round in shape. Some organisms that have camera eyes include: humans, fish, cats, birds

Compound Eyes

These eyes are made up of many smaller units called ommatidium. Organisms that have compound eyes include: insects and crustaceans (shrimp, lobster, crayfish).

