What Are Lenses?

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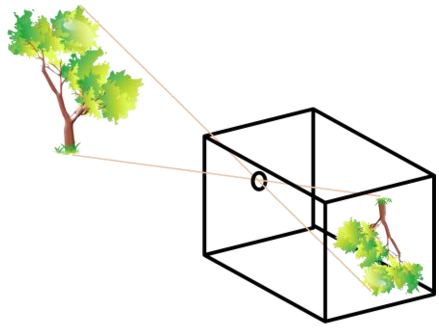
Keep it Simple

Modern photographic lenses can be extremely complex containing many different elements of differing shapes, and glasses. However, to understand the principles of a lens, it can be thought of as something much simpler: more like a simple magnifying glass.

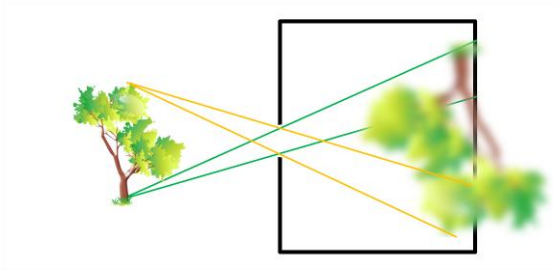


Pinhole camera

Why Have a Lens?

Pinhole cameras manage perfectly well without a lens, so what's the point?

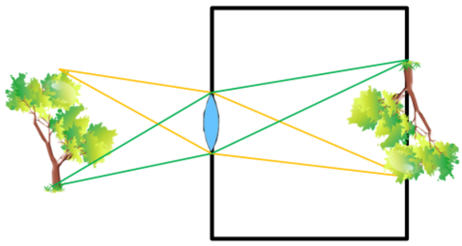
Aristotle discussed the effect of light passing through a hole (The Chinese may have been earlier.) By the ninth century, camera obscuras were being built in Baghdad. Drawings show that the idea of a pinhole was well known in the seventeenth Century.



Out of Focus Pinhole Camera

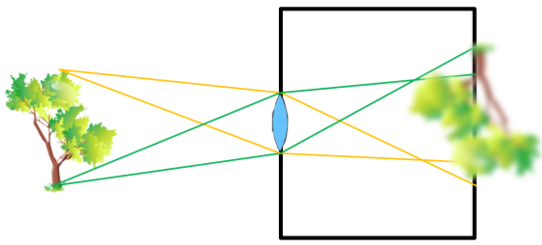
A small hole will project an inverted image. In my drawing, a ray of light from the top of the tree strikes the bottom of the screen at the back of the camera.

The problem is that not much light can get in so the image is dark. If you increase the size of the hole, then the image goes out of focus. A lens solves these problems by allowing more light to enter the camera while bringing the image into focus.



Camera with a Lens

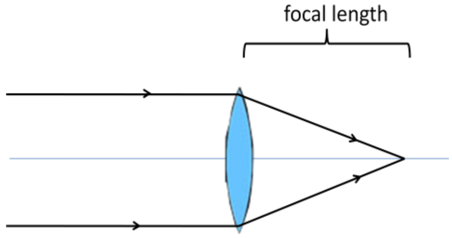
While the use of a lens solves some problems, it creates others. In particular, if the lens brings a subject at one distance into focus, another subject at a different distance will be out of focus. So, what started out as simple change to collect more light, gets a little more complex and needs a focussing mechanism.



Subject at a Different Distance is Out of Focus.

Focal Length

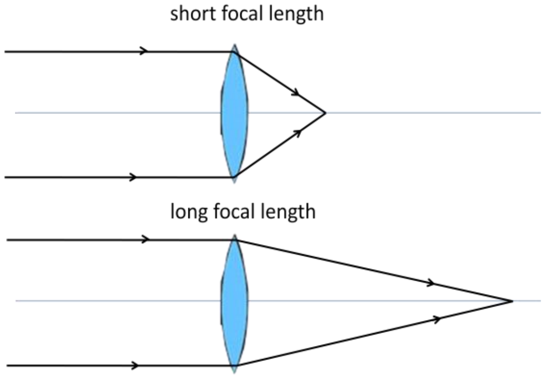
When light from a long way off (infinity!) arrives at a lens, the light will be bent and brought to a focus. The distance from the lens to where the light rays are brought together is called the focal length. This is one of the most important characteristic of a lens.



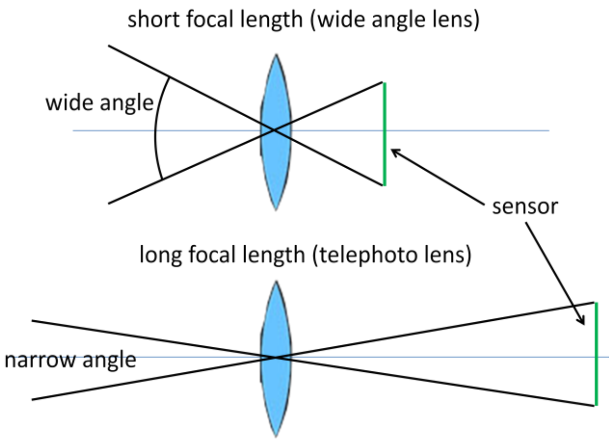
Focal Length

The ability of a lens to bring light to a focus is what enables a lens to create an image: the fundamental reason you have a lens in the first place.

Different lenses have different focal lengths. That is, the light is brought to a focus at different distances from the lens. This means that the angle of view changes. To cover the same size sensor, the short focal length lens has a wider angle of view than a long focus lens.



Different Focal Lengths



Different Angles

Wide angle Lens

Telephoto Lens

This has important consequences for taking pictures. A long focus lens, often called a telephoto, will seem to behave like a telescope. Distant subjects will seem closer.

Aperture

The aperture is the window through which the light enters. The size of the aperture can be varied by adjusting set of interlocking metal leaves known as a diaphragm.

The size of the aperture has two important features for the photographer; exposure and depth of field.

[Exposure and Depth of Field are the subject of other "Tutorials" in this series so, will only be mentioned briefly here]

Diaphragm set to different Apertures

Exposure is the ability of the photographer to control the amount of light which reaches the sensor. There are two camera controls which affect this: the aperture and the shutter. That is: how big is the window, and how long should you leave it open for.

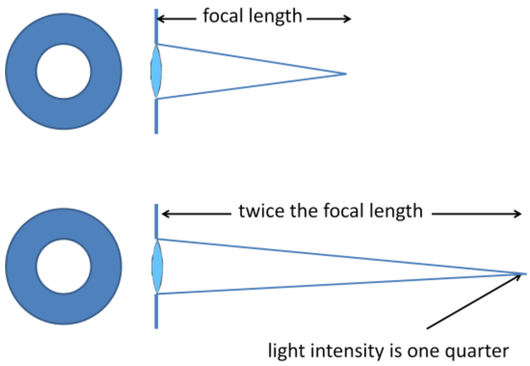
Depth of field is the amount of the image which is acceptably in focus in front of, and behind, the point of focus.

Deep and Shallow Depth of Field

F numbers

The problem with aperture is that the same diameter of aperture means different things for different focal lengths.

For the same diameter of aperture, the light intensity at the sensor reduces to a quarter at twice the focal length. It's due to something called the inverse square law. It's not actually complicated, but f-numbers were designed to make it easier. Instead of fixing the aperture and coping with varying intensity, you fix the intensity and vary the aperture.



Light Intensity Reduces with Focal Length

An f-number, such as f/8, is designed to give the same light intensity at the sensor whatever the focal length. As a photographer you work with the f-number and everything else sorts itself out!

For those who worry about these things, the f-number is defined as the focal length divided by the aperture diameter. What this means in practice is that, for a constant f-number, the aperture increases in proportion to the focal length. So, if you double the focal length, you double the aperture and, by implication the diameter of the front element of the lens. So, long lenses with a large aperture are large, heavy and expensive!

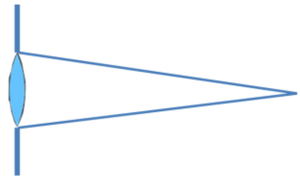
Zoom Lenses

A zoom lens has a variable focal length. This means that for a constant f-number, the front has to be large. The problem is that this large front element is not only heavy and expensive, but most of the time only the central part the lens is used.

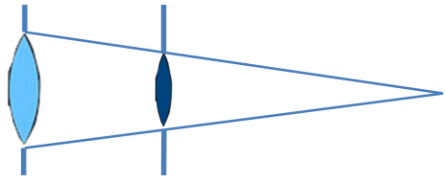
One approach to cut the weight and cost is to reduce the aperture at the long end of the zoom. This means that the lens can be made smaller and lighter (and cheaper).

The picture below shows two zoom lenses from Olympus. Both have a zoom range of 40-150mm. The larger has an aperture of f/2.8 throughout. The smaller is a stop slower (f/4) at the wide end of the zoom, and even slower (f/5.6) at the long end of the zoom.

Two Olympus lenses with the same zoom range but different apertures

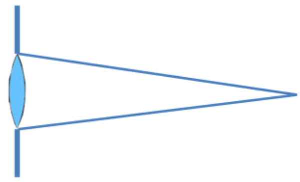


zoom lens - short focal length

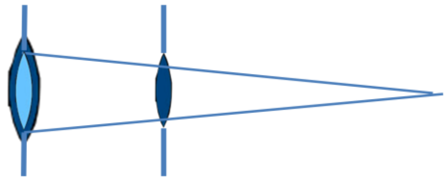


zoom lens – long focal length

For a constant f-number, a zoom lens needs a large front element.



zoom lens - short focal length



zoom lens – long focal length

Variable f-number to save the weight and size of the front element.

Lens Markings

You have probably noticed that there are lots of numbers all over a lens. Here are some examples and what they mean.

Maximum Aperture of f2.8

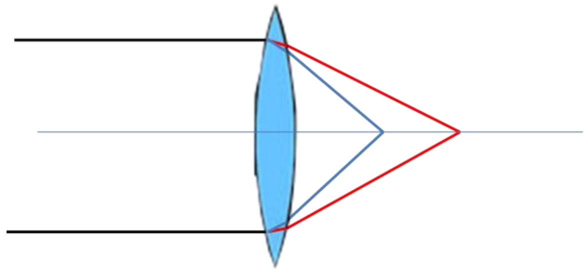
Maximum Aperture varies from f4 to f5.6

Filter Thread

Focal length

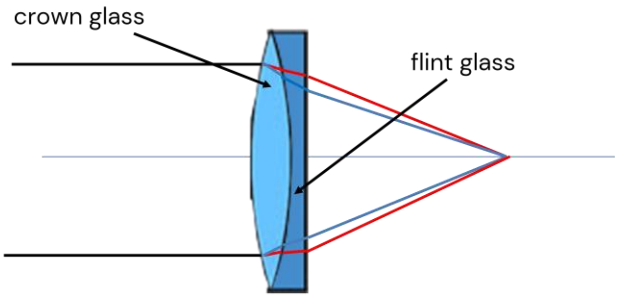
Colour Fringing

Colour fringing, sometimes called colour aberration is caused by the different colours in the light focussing at different distances.



Different colours focus at different distances

A solution to this problem was invented by Chester Moore Hall in 1729. This was the Achromatic Doublet which uses two different types of glass bend the light by different amounts to cancel out the colour fringes.



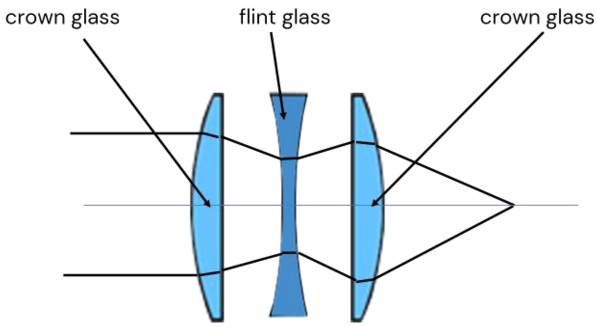
Achromatic Doublet: different types of glass bend the light by different amounts

In order to keep the invention secret he commissioned the two lenses from different opticians. Unfortunately, they both subcontracted the work to the same lens maker: George Bass.

Bass worked out what was going on and, in 1733, made a telescope for Hall based on the idea.

Hall and Bass made several more telescopes over the next 20 years, but kept the secret.

Then, in 1758, John Dolland reinvented the principle and patented it. The courts decided that while Hall had precedence, he had not brought it to market. John Dolland's name is still on the high street as the chain of opticians: "Dolland and Aitchison".



Cooke Triplet

The next significant improvement was the Cooke Triplet designed in 1893 by Dennis Taylor. He was the chief engineer at T. Cooke & Sons of York. The lens was named after his employer.

Modern lens designers are not limited to two types of glass. There are whole catalogues of glasses with different focal lengths.