Chapter 1: Imaging

An image is a visual representation in two dimensions of information.

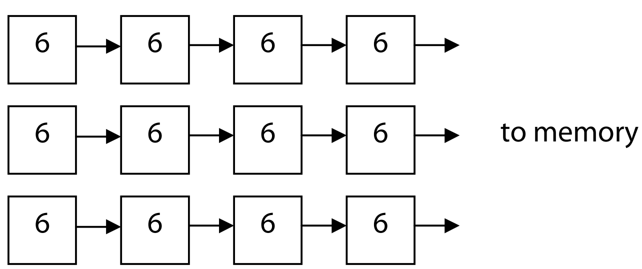
Information can be:

(i) light
(ii) x-rays
(iii) heat/infrared
(iv) ultrasound
(v) computer modelled information

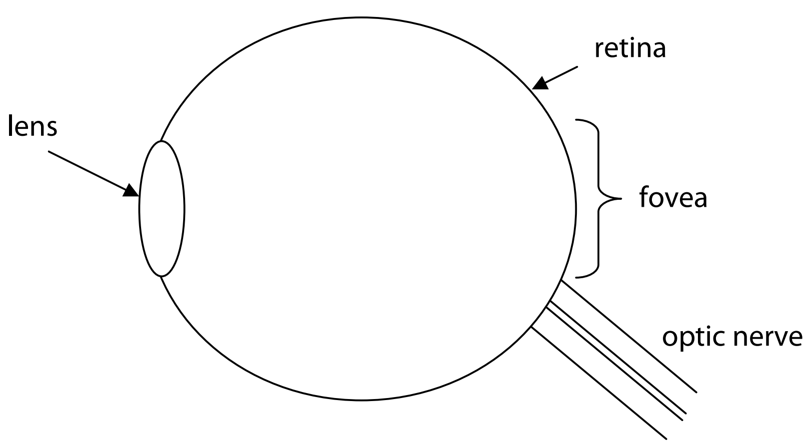
Images are made up of pixels, or picture elements. Each picture element has only one colour. On a computer each picture element is represented by a number. An image is therefore stored as a stream of numbers on a computer.

Lots of memory is required to create video images. An image of 704 x 576 pixels at 24 frames per second will require 9.73 million pixels to be processed per second.

In a digital camera CCD sensors are used. Each element accumulates a charge which is proportional to the number of light photons falling on it. After a designated time interval the pixel values are fed serially across the rows of elements. Results are stored and an image is displayed. The chip is then reset and photons are collected for another time interval. Very low light intensities can be detected if the exposure time is long enough. Different colours are detected by having colour filters over some of the elements.



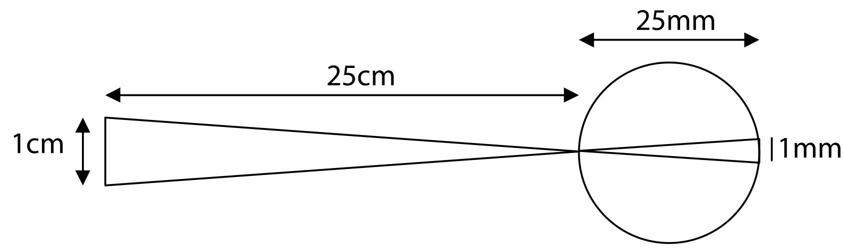
The eye



Rods: light intensity down to a low level but do not sense colour.
Cones: sensitive to colour and detail, red, blue and green detectors.

Rods are in greater concentration around the edges and cones more in the centre of the eye. The fovea is a very heavy concentration of cones.

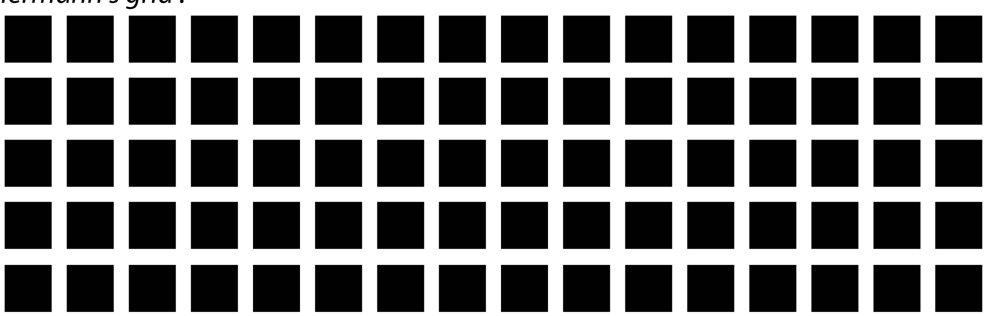
The rods at the edges give off centre vision which is why at night you can see better off centre than if you look directly at an object. The fovea is ~1mm in diameter, which can be seen by holding text 25cm from the eye. An area about 1cm in diameter is focusable. This can be seen in the similar triangles below.



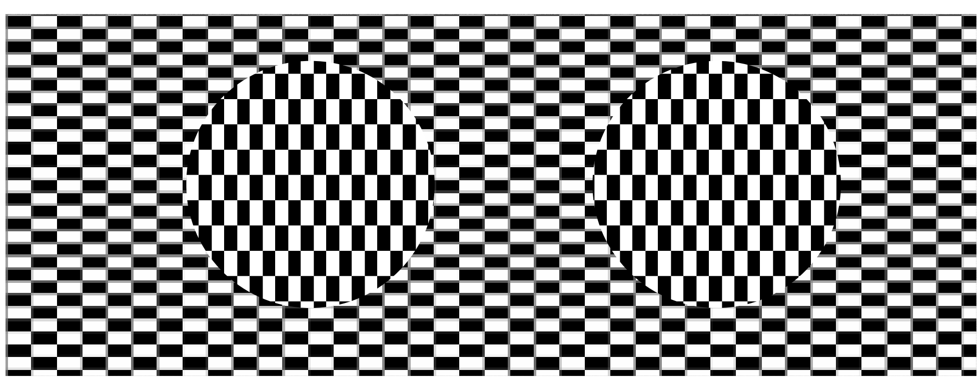
To focus the eye lens changes shape whereas a camera moves its lens back and forth.

A few illusions:

'Hermann's grid':

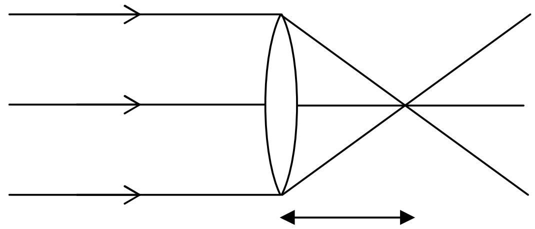


'Ouchi' illusion:



Lenses

The lens adds curvature to the wave entering it.



The central wave has gone through a thicket part of the lens so slowed down for a longer period of time than the other waves. The wave exits the lens in a curved shape. This is referred to as adding curvature to the wave.

After the focal point the waves spread out further.

Rays are shown perpendicular to the waves they represent.

The curvature of a wave is defined as $\frac{1}{r}$ where *r* is the radius, measured in metres.

The lens added curvature of $\frac{1}{f}$ where *f* is the distance of the focal point from the centre of the lens.

The lens is modelled as being thin in comparison to the focal length so the focal length is measured from the optical centre of the lend to the focal point.

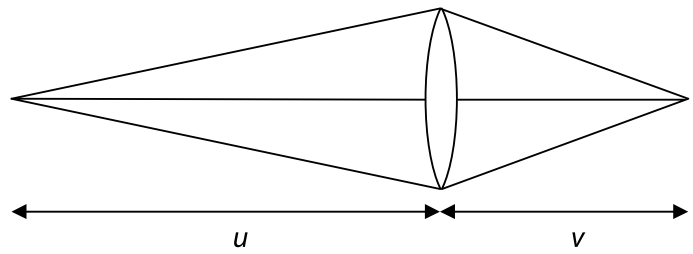
A stronger lens has a shorter focal length so a larger curvature. The curvature is used to measure the strength of a lens.

The power of a lens is defined as $\frac{1}{f}$, where power is not meant in the usual mechanical sense. Power instead here is defined as the ability to add curvature.

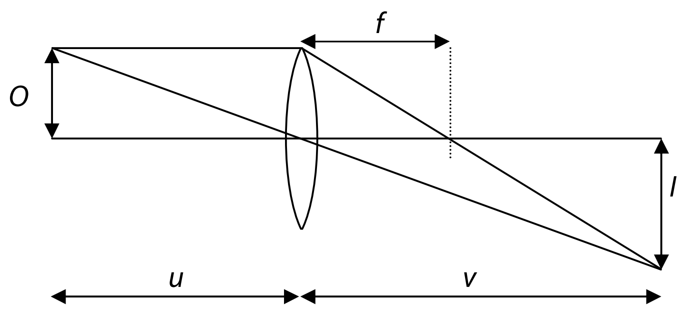
$P = \frac{1}{f}$ where *P* is measured in m^{-1} or D, dioptres.

Rays from a distant objects, for example a distant star can be modelled as producing parallel rays.

For closer objects:



So $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$, where *u* is conventionally negative and $V = U + F$ where capital letters represent the power of curvature.



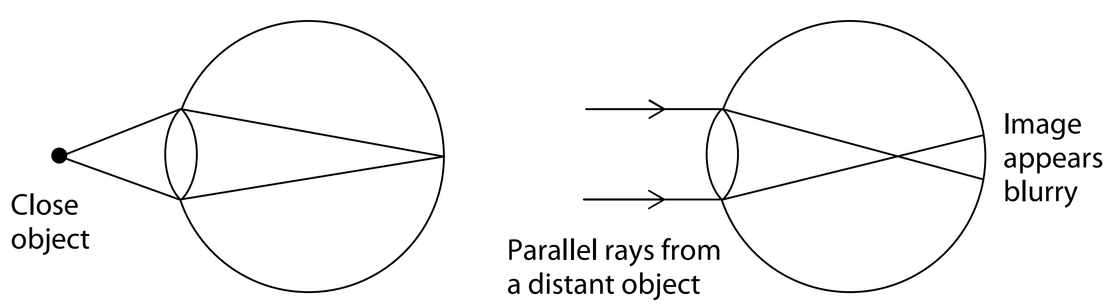
Therefore, by similar triangles, $M = \frac{I}{O} = \frac{v}{u}$ where *M* is linear magnification. *M* will always have a negative sign which demonstrates the image has been flipped and will appear upside down. The value of *M* demonstrates the scale factor of linear enlargement, so a value between 0 and -1 means that the image has been reduced in size.

Problems with lenses

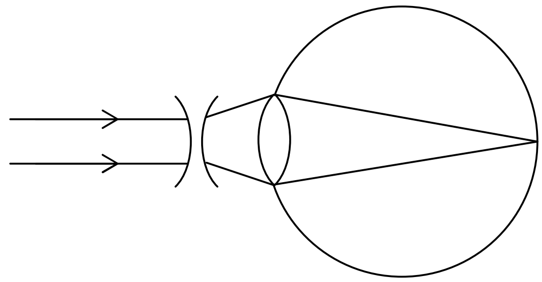
Chromatic aberration is the appearance of colour bands from old lenses.
Spherical aberration is the distortion of images through spherical lenses.

Short-sightedness

The eye can focus objects that are near to it but not distances further away as the ciliary muscles are too strong. This leads to a blurry image being created:

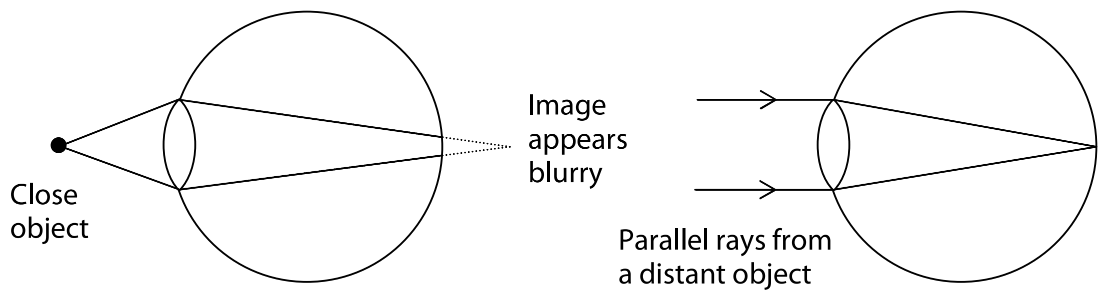


This can be corrected using a diverging lens as shown below.



This lens gives the rays a negative curvature before entering the lens so the image appears sharp on the retina. The furthest point an individual can focus without the lens is referred to as their "far-point."

Long-sightedness



This can be corrected using a convex lens as shown below.