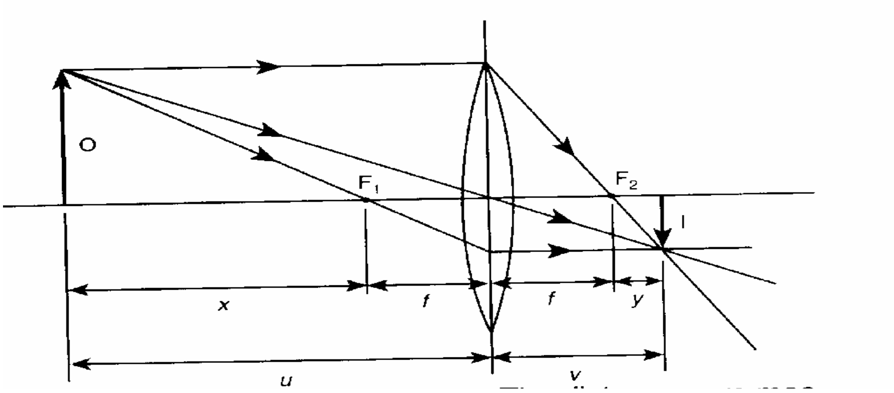
Notes from Lens Lecture with Graham Reed

Light is refracted when in travels between different substances, air to glass for example. Light of different wave lengths are refracted by different amounts.

Wave length of red is 700nm. Blue 400nm which refracts the most.

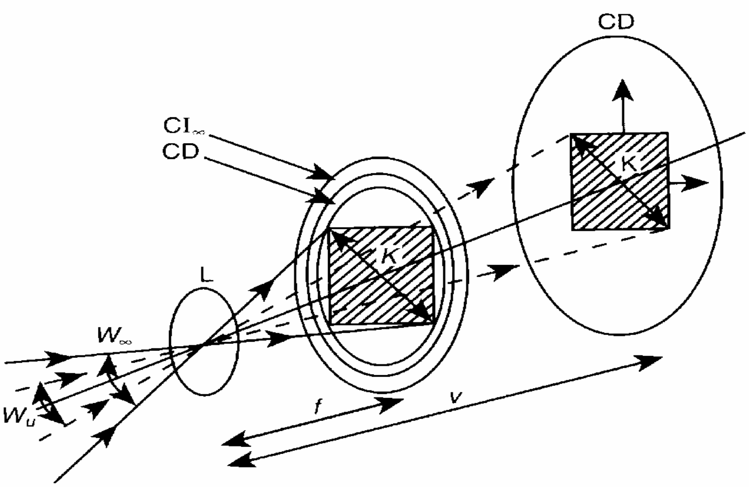


With a single lens the light from an object 'O' at distance '*u*' is brought to focus 'I' at distance '*v*' .The image is inverted.
This simple ray diagram shows how the image is formed.
'*f*' is the focal length of the lens.

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$ This is the formula for calculating the focal length of the lens.

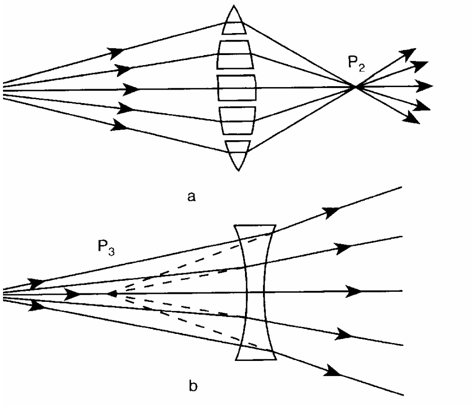
U is object distance
V is image distance
F is focal length of lens.
O is object
I is image

The focal length of a lens is defined as the distance from the lens at which the image is focused when the object is at infinity.



A positive lens forms a real image behind the lens. This is called the image circle. The illumination of this circle falls off towards the edges, gradually at first then very rapidly. The CCD should be located within the circle of good definition. (CD)

W field angle
K format diagonal
CI image circle for infinity focus



There are 2 different types of lenses

A positive lens which is convex and forms a real, positive, image

A negative lens which is concave and forms negative image

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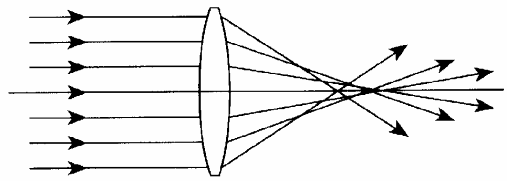
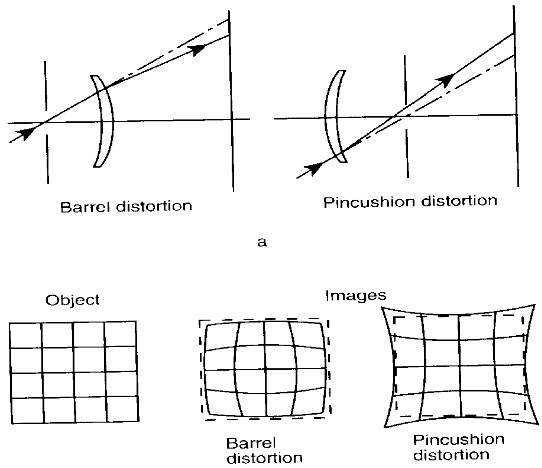
lenses



Spherical aberration in a simple lens.

A perfect lens would show a point as a point and a straight line as a straight a line but simple lenses are never perfect. These imperfections are called
<u>lens aberrations</u>

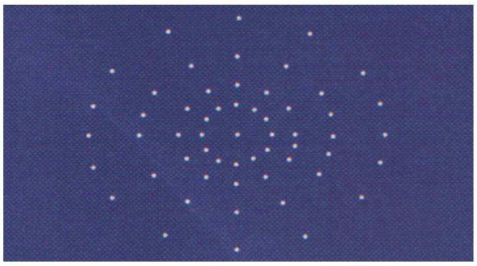
Spherical aberration is where parallel rays of light are brought to a focus closer to the lens.



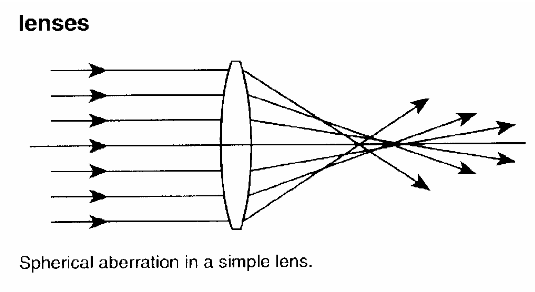
It is difficult to achieve a single lens that produces no distortion.

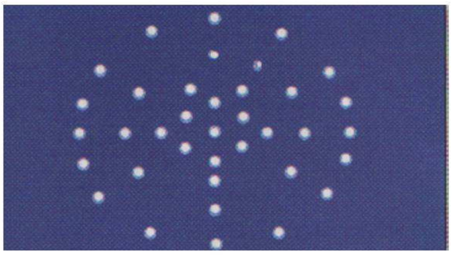
Where straight lines in the subject are distorted outwards it is called barrel distortion and inwards as pincushion distortion.

To show the effect of lens aberration we can start with an image of an array of very small light sources and observe the distortion that the lens creates.



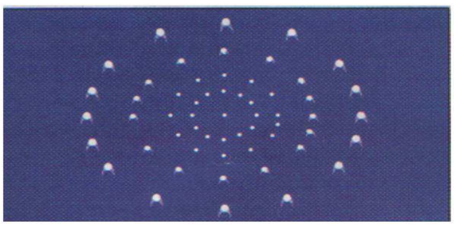
Light input into a lens element consisting of an array of infinitely small point light sources





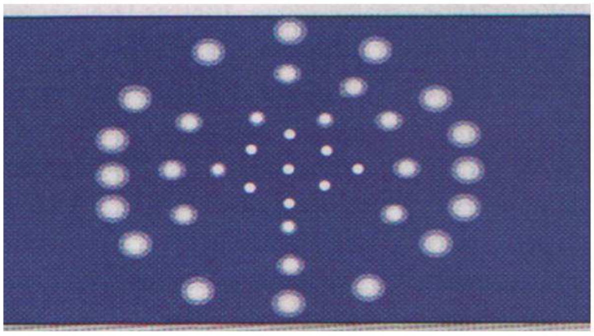
Spherical Aberration at the lens output

Spherical Aberration is differential focusing of the rays that pass through the outer edges of the lens converging at a focal point that is closer to the lens then the rays that pass through the centre point.



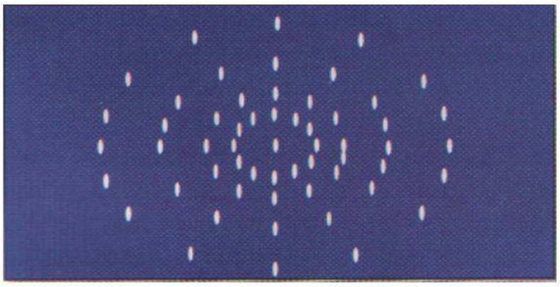
Comatic Flair

Rays from an object that is at an incident angle to the central axis can exhibit a comet –like tail instead forming a focused point.



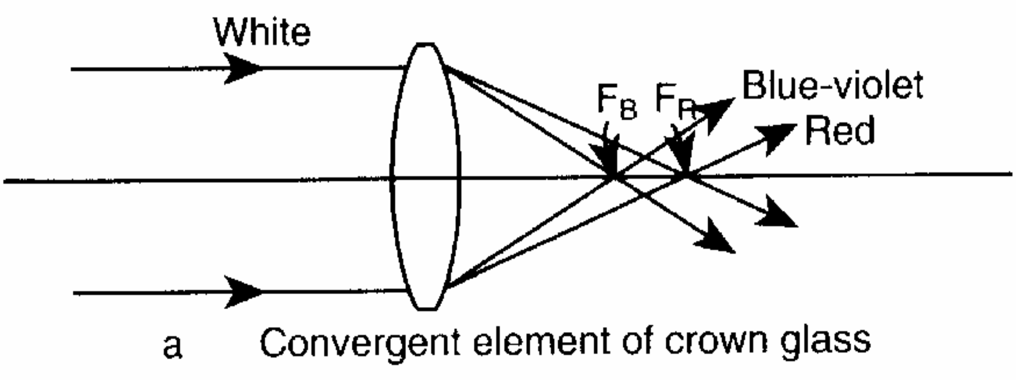
Curvature of Field

The lens fails to focus a plane optical object as a plane optical image. The centre is focused the outer edges are out of focus.



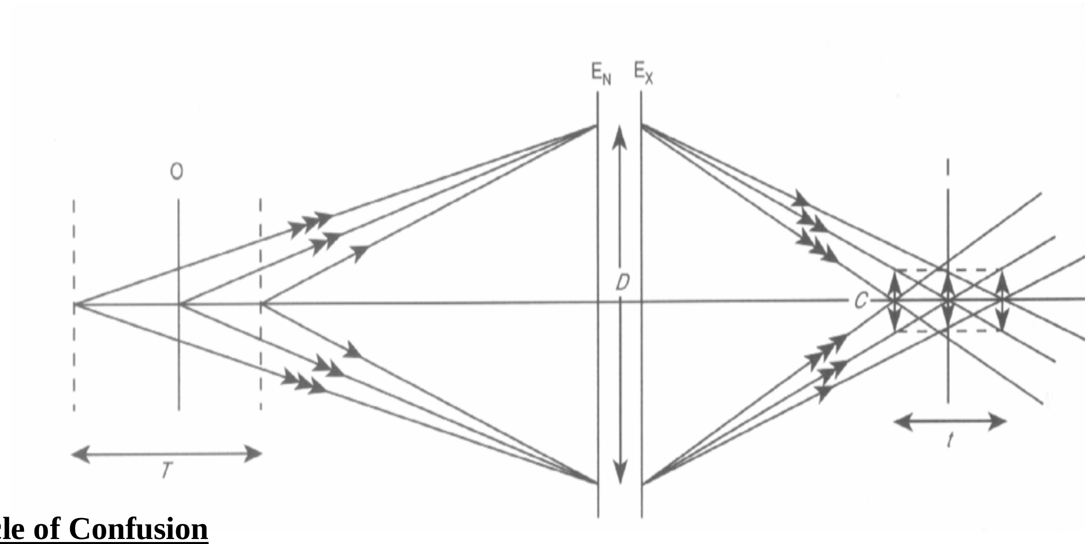
Lens Astigmatism

If a lens will not focus an off-axis point the point can become an elliptical shape or a line



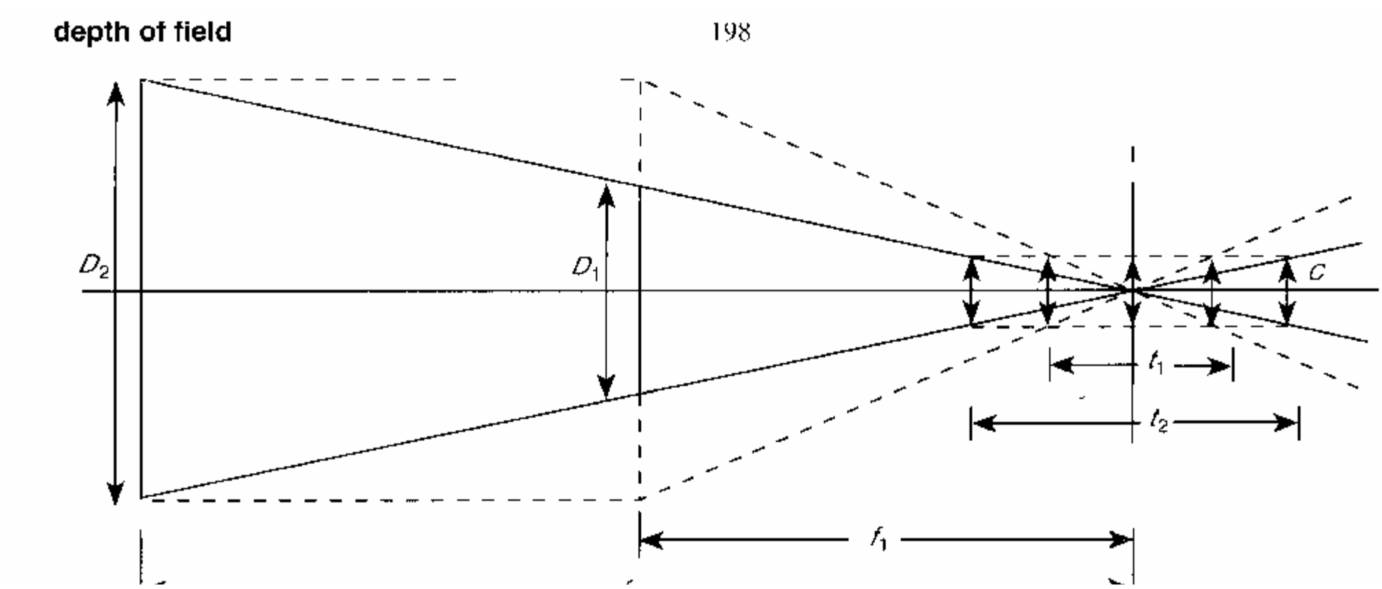
CHROMATIC ABBERATIONS.

Wave lengths of different colour focus at different points



Circle of Confusion

This can be defined as the patch of light a lens produces when it images at a point source. This patch, which is circular on the lens axis is at a minimum size when the image of the object point is critically focused. Such a circle is the circle of least confusion. The largest circle that is seen as a point rather than as a circle at a specified viewing distance is identified as the permissible circle of confusion. Depth of field (T) is the distance between the nearest object and the farthest object where points on the objects are imaged at the image plan as permissible circles of confusion. t is the depth of focus. T is the depth of field. D is the aperture



Depth of focus decreases with the increase of aperture .(*f* Number) So if D1 is increased to D2 the depth of focus is decreased from t2 to t1. C is circle of confusion.

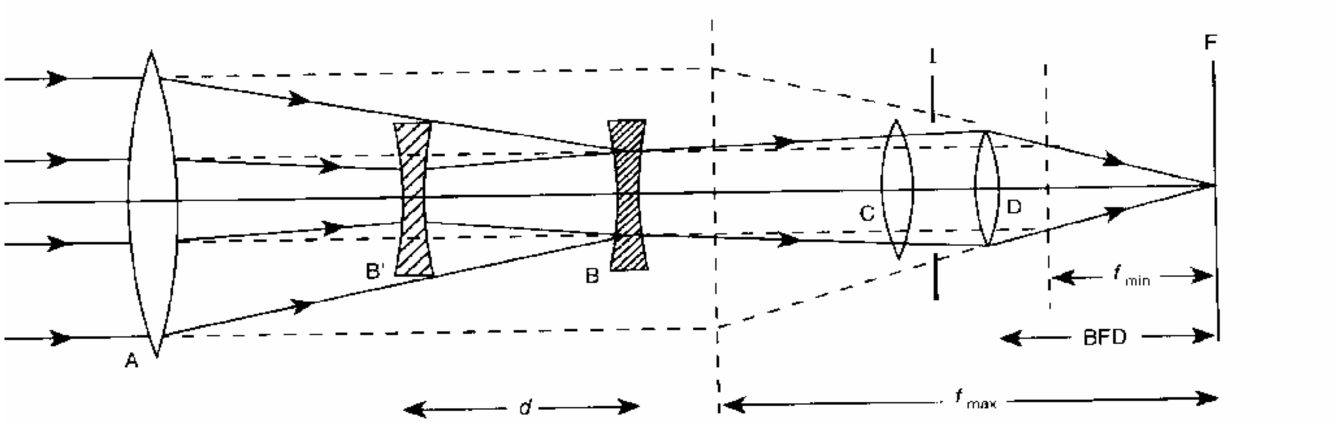
$$DoF = \frac{2u2NC}{f2}$$

Focal length = *f*
Aperture = N
Object distance = *u*
Circle of Confusion= C
Depth of field is directly proportional to the circle of confusion, the *f* number, and the square of the focusing distance and inversely proportional to the square of the focal length.

DoF increases with the distance squared
Doubling the focal length reduces the DoF (at a fixed distance) by a factor of 4.

So, a lens with a short focal length has a wide angle of view and a large DoF. Whilst, a lens with a long focal length has a narrow angle of view and a small DoF.

Basic zoom lens. A,B,C, form the basic elements. D is the relay lens which is adjusted for the back focus, (zoom tracking). BFD Back focus distance. A relay lens is used to transfer an intermediate image formed in one region of an optical system to another part by optical projection.



How to adjust back focus also called zoom tracking.

Use if possible a back focus line-up chart. If not find a object with many sharp edges. Heating grill for example. Place the camera about 1 meter from the chart and expose correctly. Make sure the viewfinder is producing the sharpest image, increase peaking to max. Zoom in and focus. Zoom out to the widest angle of lens (shortest focal length) Check that the centre of the chart stays in focus or that the image remains sharp.
If it does not release the back focus ring lock. Zoom into chart and focus. Zoom out and adjust the back focus ring. Rock through focus until you are sure of the best focus point. Carefully gently tighten the back focus ring lock. Zoom in again and re-focus, zoom out and check that the image remains in focus. If it does, carefully lock the back focus ring tightly and re-check. If the focus is not maintained repeat the procedure.

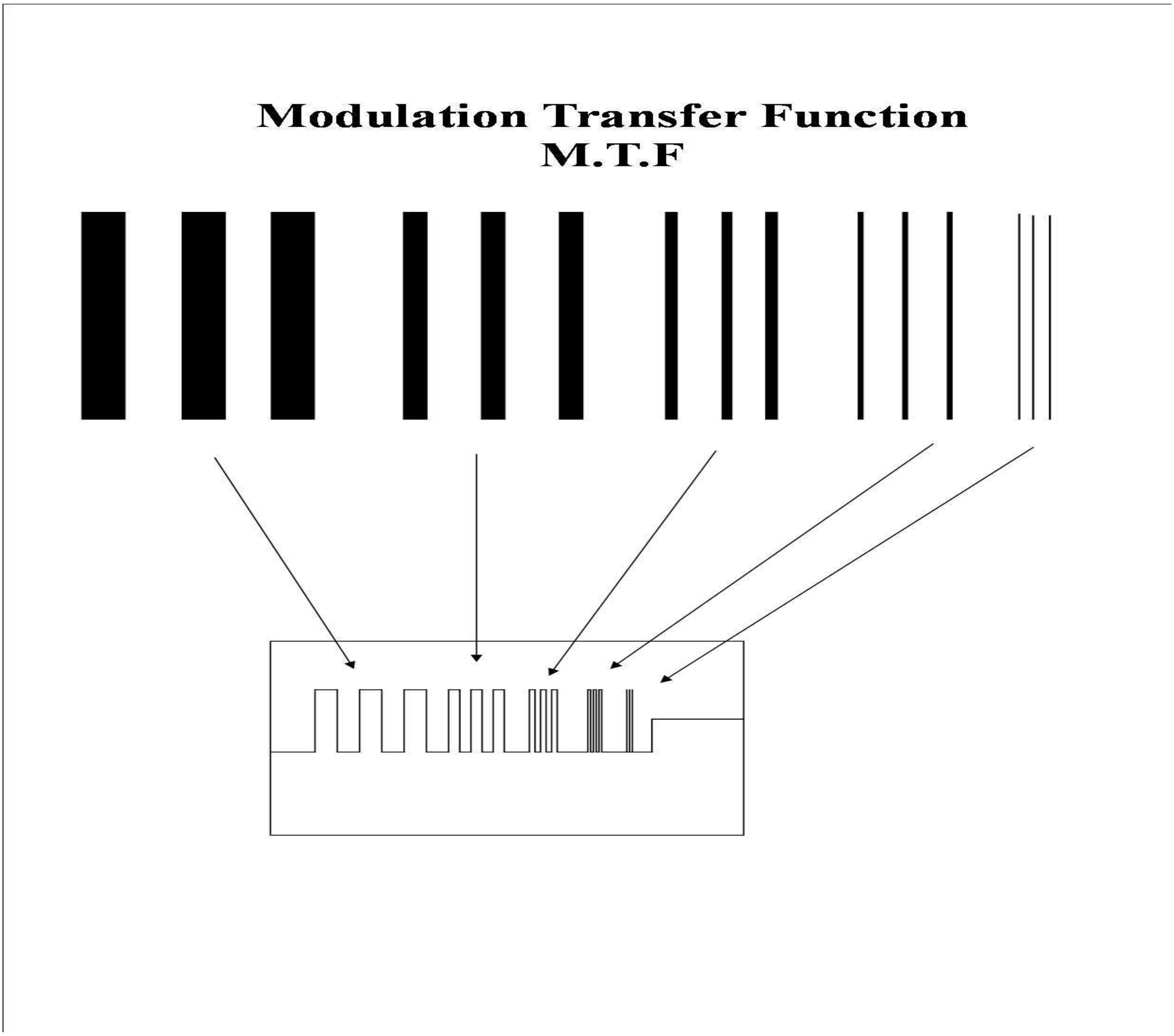
Hyperfocal Distance

Maximum depth of field in any situation is given by the hyperfocal distance set as the focused distance on the focusing scale of the lens The hyperfocal distance is defined as the focus setting that makes the far distance sharp equal to infinity, or as the nearest distance in focus when the lens is set to infinity. So if the lens is set to a distance ‘u’ then the near limit of depth of field is u/2

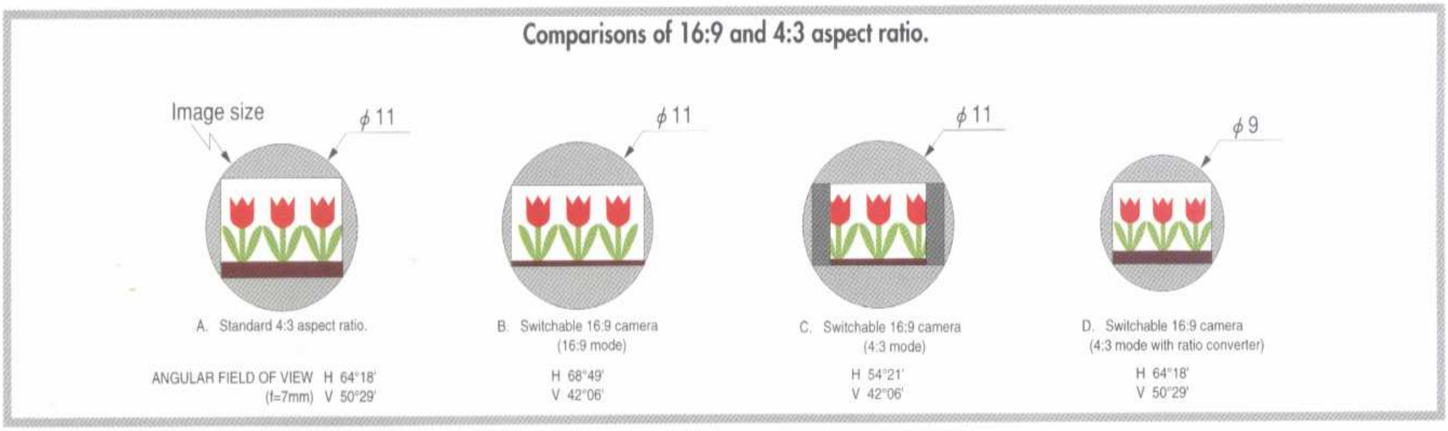
MOD.

Minimum object distance is the nearest distance a lens can focus.

M.T.F. is the method of measuring the resolution of the lens/camera system. The amount of resolution that a lens can produce is only as good as the camera system The resolution of a lens also varies across the diameter of the lens, *f* stop and focal length.
By passing through the lens/camera system an image of increasing smaller black and white lines, referred as line pairs per millimetre (LP), and measuring the output, the resolution of the system can be evaluated.



In SDTV the camera lens system should resolve 30LP/mm
In HDTV the camera lens system should resolve 84LP/mm



4:3 camera	16:9 camera 16:9 mode	16:9 camera 4:3 mode	16:9 camera 4:3 mode with switch able converter
H 64’ 18 V 50’29	H 68’ 49 V 42’06	H 52’ 21 V 42.06	H 64’18 V 50’29

Note that with the lens converter the angles of view are the same for both 4:3 camera and a 16:9 camera on 4:3 mode.

Diopter.

Unit expressing the refracting power of a lens, being the reciprocal of its focal length in meters. A +2 diopter lens is a converging lens of a focal length 500mm.

Useful web sites:

www.canon.com/bct/calculator for calculating lens angles etc.
www.camerafilters.co.uk for camera filters.