The decision as to which lens is best suited to an application can be quite a complex one, especially when several components are required in the system. Here, we will deal only with the choice of single components, which have a well defined function to perform. Some of the more complex considerations involved with multi–component systems are discussed in the ***Optical Theory*** section of the Catalog.

If you have any difficulties in selecting single lenses or the lenses for a multi–component system call Ealing for assistance.

The key parameters of a single lens are:–

1) Focal length
2) Diameter
3) Construction:– Material and Shape (form)

FOCAL LENGTH

If you do not know the actual focal length of the lens for a particular application, it can usually be determined using some fairly simple formulae.

For applications using one infinite conjugate the focal length is usually dictated by the angular field of view on the long conjugate side and the linear field of view on the short conjugate side.

Given an object field of semi–angle θ and a lens of focal length f, the radius of the image field is equal to

$$f \tan \theta.$$

For applications using two finite conjugates, the focal length required can be determined using the equations in the ***Optical Theory*** section (pg 1), if any two of the following parameters are specified:

Object distance s
Image distance s'
Magnification m
Total Track (Throw) T

The equations have been given in various forms to enable you to choose the one most appropriate to the initial conditions.

If more than two initial conditions are specified, there is the possibility that these requirements could be inconsistent. An example of such a case might be a system where an extended working clearance is required, without unduly increasing the overall length of the system. The more initial conditions specified, the more likely it is that additional components are required to satisfy them. A number of useful equations relating to two–lens systems are given in ***Optical Theory*** (pg 3) .

Having decided on the diameter and construction of the ideal lens you require, look for the closest match on focal length listed. Use the conjugate equations in ***Optical Theory*** (pg 3) to recompute the actual conjugate positions and magnification for that lens, taking into account its thickness if the application is critical.

If there is no stock lens with a focal length close enough, but you would rather avoid non–standard components, then you can convert the required focal length into a lens power and see whether a combination of two standard lenses have powers which add up to the desired value. The equations for combining lens powers are given in ***Optical Theory*** (pg 3). Both lenses can be oriented independently in the way most suitable to reduce the aberrations of the combination, so a degree of correction surpassing a single lens can be obtained in some cases.
Other focal lengths can be supplied – contact the Ealing Sales Department for your special requirements.

SELECTING SINGLE LENSES – TECHNICAL CONSIDERATIONS

DIAMETER

In a system containing many components, clear diameters of the lenses are determined by two factors – the required Numerical Aperture and Field of View of the overall system. The best way to determine approximate values for the clear diameters in this case is to use the paraxial raytrace equations in ***Optical Theory*** (pg 5 & 6).

In a simple system involving either one component or several components close together, the lens diameter itself often forms the location of the aperture stop and directly determines the numerical aperture. In these cases the field of view may play a minor role in determining the clear diameters required.

If you are working with beams with a Gaussian intensity distribution, for example a He–Ne or Semiconductor laser, it is often advisable to allow for a clear aperture some 30% larger than the $1/e^2$ diameter, to reduce the effects of diffracted light on the focused beam.

In most cases you simply select the nearest lens diameter greater than the clear aperture required, subject to the other conditions on focal length and construction. However, if the lens you intend using is an achromatic doublet, it is advisable not to specify diameters far larger than required as the aberration balance across the aperture will be optimized in a different way (see ***Optical Theory*** pg 14).

It is often overlooked that the mount in which the lens is held will, in most cases, reduce the clear aperture to a value less than the physical diameter of the lens. Remember to allow for this, especially on very small components where the mounting shoulder can be a significant fraction of the lens diameter.

Most lenses can be edged to meet specific mounting requirements – contact the Ealing Sales Department with your special requirements.

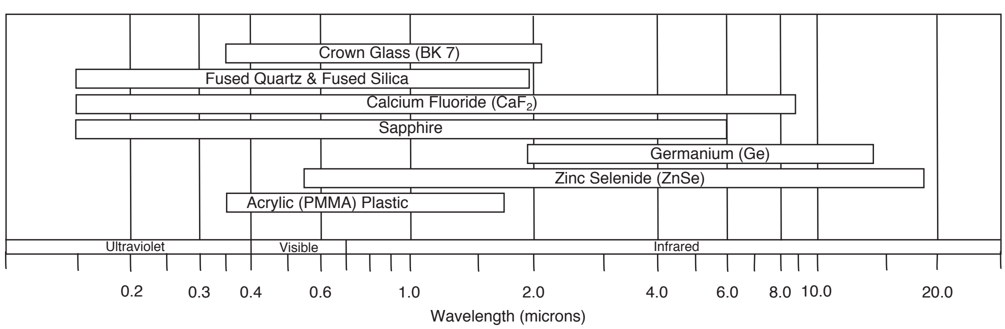
CONSTRUCTION

The construction of a lens breaks down into two distinct parts – Material and Form.

Material

The principal purpose of a lens is to redirect radiation from one location to another, whether that be for imaging or non–imaging purposes. With this in mind it is important to select lenses constructed out of materials which have high internal transmission within the spectral region of interest.

The material selection chart below gives a broad overview of the transmission bands of materials used in the construction of Ealing standard components. More precise transmission data is available in the ***Optical Materials*** section of the Catalog.



Lens Material Selection Chart - Optimum Transmission Bands

CONSTRUCTION (continued)

From a glance at the chart one can see that in certain parts of the spectrum there are many possible alternatives which could be chosen. In these cases a secondary criterion such as the ability to withstand thermal shock, or an economic factor may determine the final candidate.

For work in the visible region and for the Infrared up to around 2.5 microns, BK7 optical glass is the most economical solution, although if you have special resolution requirements you may need the improved performance obtainable from an achromatic doublet.

If the lens is likely to be exposed to a particularly harsh environment or excessive thermal conditions it may be necessary to consider fused quartz, fused silica or even sapphire. These materials are more expensive although they all in general have more extended ranges of transmission than BK7. In visible applications they are used primarily for their physical, rather than their optical qualities, unless the system is used with UV or IR as well. As Fused Silica has a very low absorption throughout the visible region, it is sometimes preferred to the specially purified grades of BK7 which are required for high power laser applications.

In the Ultraviolet region below 350nm most standard Optical Grade glasses have poor transmission. The most likely choice for a lens in this region is Fused Silica or Fused Quartz, although Calcium Fluoride is an alternative possibility. As most grades of Fused Quartz start to absorb below 280nm then UV grade Fused Silica is to be preferred here. With the limited choice of materials for this region, chromatic correction is more difficult, although Calcium Fluoride and Fused Silica act respectively like Crown and Flint glasses. In many cases reflecting systems (such as the Ealing Reflecting Objectives) provide a superior alternative.

In the Infrared region the most likely materials to be used are Germanium and Zinc Selenide. These are described in greater depth in ***Optical Materials*** (pgs 5 & 6). In short, Germanium is the less expensive material and transmits at wavelengths greater than 2 microns. It should be avoided with beams of high power density, or if the temperature exceeds 50 degrees C. Zinc Selenide is more suitable for high power applications and also transmits visible light well enough to aid alignment. Both these materials have high refractive indices and generally require anti–reflection coatings to ensure adequate performance.

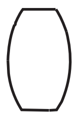
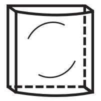
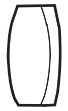
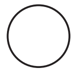
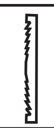
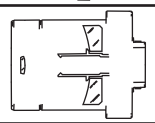
Form

Lenses can be constructed with surfaces that are flat, spherical or aspherical. The many different types that are available from Ealing are summarized in the table on the following pages.

Please note that Ealing can also supply lens mounts.
Standard holders are available at ***ealingcatalog.com***

SELECTING SINGLE LENSES – OVERVIEW OF THE EALING RANGE

SELECTING SINGLE LENSES – OVERVIEW OF THE EALING RANGE

FORM		MATERIAL	STANDARD SIZE (DIAMETER)	FOCAL LENGTH	COMMENTS
PLANO–CONVEX		BK7	12.5 to 100mm	15 to 1000mm	Most suitable where one conjugate is more than five times the other, e.g. in sensor applications or for use with near collimated light. Also where both conjugates are on the same side of the lens, e.g. as an add–on lens to increase the numerical aperture.
		Fused Silica & Fused Quartz	12.7 to 50.8mm	12.7 to 304.8mm	
		Calcium Fluoride	25.4 to 76.2mm	50 to 500mm	
		Sapphire	5 to 20mm	5 to 100mm	
		Micro Lens LaSFN9	1.5 to 2.5mm	1.0 to 2.5mm	Short focal length lenses for miniature applications.
		Germanium Zinc Selenide	12.7 to 50.8mm	25.4 to 500mm	Most suited for lower aperture (higher F/No.) applications, where the extra cost of a best form meniscus is not justified.
EQUI–CONVEX		BK7	12.5 to 100mm	15 to 1000mm	Most suitable where the conjugates are on opposite sides of the lenses and the ratio of the distances is less than 5:1, e.g. as simple image relay components.
PLANO–CONCAVE		BK7	12.5 to 50mm	–15 to –1000mm	Negative lens with the form most suitable where one conjugate is more than five times the other, e.g. producing divergent light from a collimated input beam.
		Fused Silica & Fused Quartz	12.7 to 25.4mm	–25.4 to –304.8mm	
		Calcium Fluoride	25.4 to 50.8mm	–50 to –250mm	
		Sapphire	5 to 20mm	–5 to –100mm	
EQUI–CONCAVE		BK7	12.5 to 50mm	–15 to –1000mm	Negative lens with a form most suited to producing diverging light or a virtual image, where the input light is converging.
MENISCUS (POSITIVE)		BK7	12.5 to 50mm	25 to 400mm	These lenses may be used to increase the numerical aperture of a positive lens assembly, without an undue increase in the aberrations.
MENISCUS (POSITIVE & NEGATIVE)		Germanium	12.7 to 50.8mm	13 to 200mm –13 to –125mm	The best lens form where one conjugate is relatively far from the lens or where both conjugates are the same side of the lens.
		Zinc Selenide		13 to 203.2mm –13 to –150mm	
CYLINDRICAL		BK7	12.5 to 50mm wide 20 to 130mm long	22.2 to 300mm	Used to provide focusing power in one section only. For illumination or detection of light from line sources. Also used for anamorphic compression of beams and images.
CEMENTED ACHROMATIC DOUBLETS		Combinations of two Optical Grade Glasses	6 to 80mm	10 to 1000mm	These lenses have considerably reduced values of Spherical Aberration, Coma and Chromatic Aberration. Best used to replace single components where performance must be improved.
BALL		BK7	1 to 10mm	0.73 of the Diameter	Used to provide short focal lengths for use with collimated light. Often used in fiber coupling applications.
CONDENSER QUALITY ASPHERICS		Crown Glass	15 to 70mm	12 to 68mm	Used to provide high aperture (low F/No.) light capture and focusing. They are capable of a performance which would otherwise require a multi–component system.
FRESNEL		Acrylic	25 to 470mm	10 to 610mm	Their thin construction provides a high diameter to weight ratio. Large diameter and fast F/No. components can be constructed which would be impracticable using conventional methods.
REFLECTING OBJECTIVES		High Reflectivity Mirrors	0.28 to 0.65 N.A.	2.5 to 13.5mm	The two–mirror design of these Reflecting Objectives makes them ideal for beam delivery and light gathering applications where a broad spectral response and freedom from chromatic aberration are required.