# Focusing



A lens, at a given focus setting, provides a sharp image of an object at only one distance in front of it. However, when the distance between the focal plane and the lens can be adjusted, the lens can be made to form sharp images of objects located at differing distances. Therefore, to get a sharp image of a subject at a given distance, you must adjust the lens to the appropriate distance from the film plane. This adjustment is known as focusing. In focusing a camera lens, the nearer the subject is to the lens, the farther behind the lens the image is formed. For close subjects, the lens must be moved away from the film plane to focus the image; and the farther away the subject is from the lens, the closer to the lens the film plane must be.

## Infinity Focus

When the lens is focused on an object so distant that the light rays reflected from it are parallel, these rays converge (after refraction by the lens) at the point of principal focus. The point of principal focus is on the principal focal plane; that is, at a distance of one focal length behind the lens. Therefore, the lens is said to be on infinity focus. When the distant object is moved nearer to the lens or the lens is moved closer to the object, the distance between the focal plane and the lens must be increased to keep the image in sharp focus. When the distance between the lens and focal plane is not extended as the object is moved nearer to the lens, the image of the object becomes blurred or out of focus. The closer the lens is to the object it is focused upon, the larger the image becomes until the distance between the lens and the focal plane is extended to twice the focal length of the lens. At this distance, the image and the object focused upon are the same size. Therefore, the size of an image formed by a lens is dependent upon two factors:

1. The distance from the lens to the object focused upon
2. The focal length of the lens

## Focusing For One Object

Focusing is done essentially to obtain the proper distance between the lens and the film. When light rays come from an object and pass through a lens, they form a sharp image on the film just past the lens.

## Circle of Focus

A picture is an accumulation of many points that are exact images of points composing the subject. After light strikes a subject, it is reflected from many points on the subject. A camera lens redirects these reflected rays into corresponding points on the film. Each of these points is reproduced by the lens as a circle. When the circle is smaller than l/100 inch, it appears as a sharp point to the eye. When the circle is larger than 1/100 inch, the eye sees it as a circle, and the image is blurred or out of focus. Each out-of-focus circle on the film is a cross section of a cone of a light ray.

When a lens is focused on an object at a certain distance, other objects, both closer and farther than the focus distance, form larger circles on the film. When the film is placed at a point corresponding to the lens focus distance, a clear image is produced. When the film is nearer or farther away from the lens than the corresponding lens focus distance, the image becomes blurred because of the larger circles caused by the intersection of light rays either in front of, or behind, the film plane.

## Circle Is Dependent on Film Size

16mm, 35mm, 2 ¼ x 2 1/4 ", 4 x 5", 8 x 10", all correspond to different film thicknesses of 0.0010, 0.002, 0.004, 0.006, 0.012 Diameter (inches).

Another factor affecting us is lens aperture. Decreasing a lens opening narrows the light rays passed by the lens. The narrower these rays, the smaller the circles when the image is not in perfect focus. In practice, this means that a small lens opening is used to record, as clearly as possible, several objects at varying distances. Even when the rays from some objects do not intersect perfectly at the film plane, the circles ahead or behind the film are negligible and still appear as a sharp image. The size of the permissible circles depends on the film format size and the manner in which the film will be used. Experience has shown that the permissible acceptably sharp focus should not exceed about 1/1000 of the focal length of the lens. This is normal for the film size.

# Hyperfocal Focus

The hyperfocal distance of a lens is the distance from the optical center of the lens to the nearest point in acceptably sharp focus when the lens, at a given f/stop, is focused at infinity.

Wow! Is that confusing? Let me try to say it differently. When a lens is focused at infinity, the distance from the lens beyond which all objects are rendered in acceptably sharp focus is the hyperfocal distance. For example, when a 155mm lens is set at f/2.8 and focused at infinity, objects from 572 feet to infinity are in acceptably sharp focus. The hyperfocal distance therefore is 572 feet. The following equation is used to find hyperfocal distance:

$H = F^2 / f \times C$

- H = Hyperfocal distance
- f = f/stop setting
- C = diameter of circle of focus
- F and C must be in millimeters
- ND = Near Distance
- FD = Far Distance
- D = Distance
- F = Focal Length of lens

(This key will be helpful other places on in this article.)

NOTE: 1 inch is equal to 25.4mm.

Where: F = 155mm (6.1 inches) f = 2.8 C = 0.05 (0.002 inches) Then: $H = 6.1^2$ 2.8 x 0.002 = 6650 inches = 554 feet. Thus, the hyperfocal distance for this lens set at f/2.8 is 554 feet. Hyperfocal distance depends on the focal length of the lens, the f/stop being used, and the permissible circle of focus. Hyperfocal distance is needed to use the maximum depth of field of a lens. To find the depth of field, you must first determine the hyperfocal distance. By focusing a lens at its hyperfocal distance, you cause the depth of field to be about one half of the hyperfocal distance to infinity. $ND = H \times D / H + D$

# Depth of Field

Depth of field is the distance from the nearest point of acceptably sharp focus to the farthest point of acceptably sharp focus of a scene being photographed. Since most subjects exist in more than one plane and have depth, it is important in photography to have an area in which more than just a narrow plane appears sharp. Depth of field depends on the following factors:

1. The focal length of a lens
2. The lens f/stop
3. The distance at which the lens is focused
4. The size of the circle of focus

Depth of field is greater with a short focal length lens than with a long-focal-length lens. It increases as the lens opening or aperture is decreased. When a lens is focused on a short distance, the depth of field is also short. When the distance is increased, the depth of field increases. For this reason, it is important to focus more accurately for pictures of nearby objects than for distance objects. Accurate focus is also essential when using a large lens opening. When enlargements are made from a negative, focusing must be extremely accurate because any lack of sharpness in the negative will be magnified in proportion to the enlargement. When a lens is focused at infinity, the hyperfocal distance of that lens is defined as the near limit of the depth of field, while infinity is the far distance. When the lens is focused on the hyperfocal distance, the depth of field is from about one half of that distance to infinity.

Many photographers actually waste depth of field without even realizing it. When you want maximum depth of field in your pictures, focus your lens on the hyperfocal distance for the f/stop being used, not on your subject, which of course would be farther away than the hyperfocal distance. When this is done, depth of field runs from about one half of the hyperfocal distance to infinity.

There are many times when you want to know how much depth of field can be obtained with a given f/stop.

The easiest way to do this is to use the stop down lever available on most 35mm and larger cameras. A small problem might make this problematic. This problem is in the situation where the subject is not well lit, and looking at the stopped down image in the camera is not easy to see. Under these conditions, some method other than sight must be used to determine depth of field. Depth of field can be worked out mathematically.

The distance, as measured from the lens, to the nearest point that is acceptably sharp (the near distance) is as follows:

$ND = H \times D / H + D$

The distance, as measured from the lens, to the farthest point that is acceptably sharp (the far distance) is as follows:

$FD = H \times D / H - D$

EXAMPLE: What is the depth of field of a 155mm (6.1 inch) lens that is focused on an object that is ten feet from the camera lens using f/2.8?

By the formula above, the nearest sharp point is determined as follows: ND = 9.8 feet. Thus the nearest point in sharp focus is 9.8 feet from the lens that is focused on an object at 10 feet, using f/2.8. In addition, by the formula, the farthest point in sharp focus can be determined as follows: FD = 10.2 feet. Therefore, the far point in sharp focus is 10.2 feet when focused on an object at ten feet, using f/2.8. Consequently, the depth of field in this problem equals the near distance subtracted from the far distance (10.2 - 9.8 = 0.4-foot depth of field). Thus, all objects between 9.8 and 10.2 feet are in acceptably sharp focus. When this depth of field is not great enough to cover the subject, select a smaller f/stop, find the new hyperfocal distance, and apply the formula again.

Here is the problem many people have with all these formulas. Many artists are not the greatest with mathematical formulas. If this describes you, here is some good news! Most cameras and lenses have depth of field indicators that show the approximate depth of field at various distances and lens apertures. By bringing the distance focused upon to a position opposite the index mark, you can read the depth of field for various lens openings. Keep in mind that a depth of field scale, either on the camera or on the lens, is for a given lens or lens focal length only. There is no universal depth-of-field scale that will work for all lenses.

In conclusion, the two formulas used to compute depth of field serve for all distances less than infinity. When the lens is focused on infinity, the hyperfocal distance is the nearest point in sharp focus, and there is no limit for the far point.

## Image Sharpness

The outer edges of a lens are least likely to produce a well-defined or aberration-free image, especially in the corners. Therefore, proper use of the diaphragm, aperture, or f/stop can improve image sharpness by blocking off light rays that would otherwise pass through the outside edges of a lens. There is a limit to how far the aperture can be stopped down and still increase image sharpness. When the aperture is very small, it causes diffraction of light rays striking the edge of the diaphragm. Diffraction results in a loss of image sharpness. This loss of image sharpness is especially noticeable in copy work and in scanning. Physical limitations in the design of lenses make it impossible to manufacture a lens of uniform quality from the center to the edges. Therefore, to obtain the best quality with most lenses, you can eliminate the edges of the lens from being used by closing down the aperture about two f/stops from wide open. This recommended adjustment, is called the optimum or critical aperture. The optimum aperture for a particular lens refers to the f/stop that renders the best image definition. This is one reason why many photographers tend to use apertures in the middle of what the lens can handle. When a lens is stopped down below the optimum aperture, there is an actual decrease in overall image sharpness due to diffraction. Although the depth-of-field increases when a lens is stopped down below the optimum aperture, image sharpness decreases. Therefore, increased depth of field should not be confused with image sharpness. For example, the image formed by a pinhole camera has extraordinary depth of field but lacks image sharpness. When the lens aperture is closed down to the size of a pinhole, it behaves like one. This is an important factor for subjects in a flat plane (such as copying) where depth of field is not needed.

# Depth of Field

Depth of field is that zone both in front and behind your subject that are in acceptably sharp focus. The focusing controls on most cameras are easy to use, providing you understand the factors that effect depth of field. To produce professional quality photographs, you must know how to control the depth of field. Aperture, or f/stop, is the most important factor in controlling the depth of field. The smaller the f/stop opening, the greater the depth of field; for example, at f/16, a normal lens focused on a subject sixteen feet from the camera may show everything in focus from eight feet to infinity. At f/5.6, depth of field may range from about three feet in front of the subject to about six feet behind the subject. At f/2, only the subject focused on is sharp.

Camera-to-subject distance also has an effect on the depth of field. In general, the closer you are to the subject, the shallower the depth of field. Even at f/16 with a normal lens, if you focus on a subject only three feet from the camera, the depth of field may only be about one foot. At f/2, the subject's eyes may be in sharp focus, but the nose and ears are probably going to be blurred. As you increase the camera-to-subject distance, the depth of field increases rapidly. Using an aperture of f/16 and focusing at six feet, the depth of field may extend from a foot in front of the subject to about three feet in back of the subject. Still using f/16 but focusing now at about sixteen feet, the depth of field is almost at infinity.

Most normal lenses for 35mm cameras produce these maximum ranges of sharpness at about sixteen feet. Focusing any farther from the camera only reduces foreground sharpness. You must remember this point when attempting to get the greatest possible depth of field. Lens focal length is also a factor in depth of field. The shorter the focal length of the lens you are using, the greater the depth of field at a given aperture. In other words, a wide-angle lens provides greater depth of field at f/8 than a normal lens, and a normal lens provides more depth of field at f/8 than a telephoto lens. You know that a small aperture like f/16 provides more depth of field than a wide aperture like f/2.

With experience, you can predict the best aperture for the depth of field desired. Even with experience, you do not always have to guess the aperture setting or calculate the hyperfocal distance, near distance, and far distance by using formulas. Most lenses have a depth-of-field scale to guide you. The depth-of-field scale indicates the distance range from the camera that the subject(s) appear in acceptably sharp focus. The depth of field on an SLR is marked between the aperture ring and the focusing scale. Use the depth-of-field scale as follows:

1. Focus on the subject
2. Select the f/stop
3. Check the depth-of-field scale
4. Locate the marks that correspond to your chosen f/stop
5. Read the two distances on the focusing scale that are adjacent to the two f/stops

At any given aperture, depth of field is maximized by focusing the lens at the hyperfocal distance. That is the closest point of acceptable sharp focus shown on the depth-of-field scale when the lens is focused at infinity. When you are changing the focus setting to the hyperfocal distance, the zone in front of the subject that is sharp is increased, and infinity is still the farthest point. The f/stop appears twice, once on either side of the scale centerline.

The lenses of modern SLR cameras stay at their maximum aperture until the shutter is tripped. These lenses provide a bright image in the viewfinder in order to allow you to focus. As a result, when you look through the viewfinder, you only see the depth of field for the maximum aperture and not the working f/stop. Most SLR cameras have a depth-of-field preview button to compensate for this. When you press it, the aperture closes down to the set f/stop. Although the viewfinder becomes darker, you can see the actual depth of field at the selected aperture.