SOME SIMPLE FACTS ABOUT YOUR CAMERA LENS AND HOW IT WORKS PART ONE

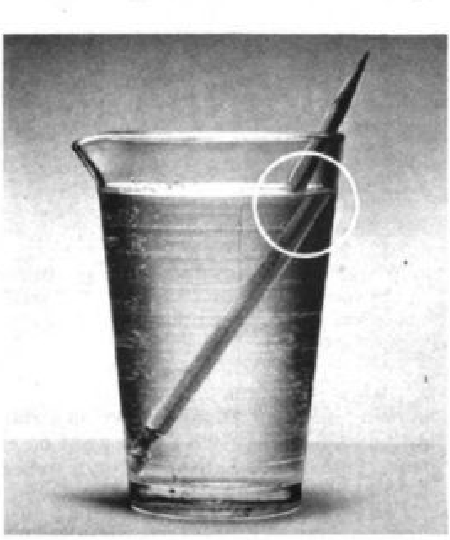
By DON D. NIBBELINK, A.R.P.S., A.P.S.A.

DID you ever stop to wonder about a camera lens and what makes it work? The simple facts about a lens are very interesting and easily understood, and some knowledge of basic lens functions can help in several practical ways with your everyday picture taking. And that's not all. You will discover that pictures can be taken with an old spectacle lens if of the proper type, or that you don't even need a lens in the simplest form of camera.

An easy way to understand how a lens works is first to look back to the time when there were no cameras as we know them today. Yet it was possible to produce an image with what we would now call a pinhole camera. A pinhole camera is nothing more than a simple box. The film is located at one end and a tiny hole or aperture to admit light for the exposure is provided at the opposite end. This minute aperture may be formed by driving a pin through the pasteboard of the box, or better yet, by making a hole with a small sized needle in a piece of black paper or tinfoil and attaching this over an opening in the end of the box.

You might ask why such cameras aren't used today when they are obviously so inexpensive. Well, the answer is that they are used in some special instances by artistic photographers, but there are several disadvantages of a pinhole "lens" that make it unsuited for general picture taking in present day practice.

Although the pinhole is free from many of the common lens defects, it lets in very little light, and therefore necessitates very long exposures—often up to several minutes even in good light with modern negative materials. Naturally, there was a desire on the part of the ambitious experimenters of early times to take instantaneous pictures which were sharp—



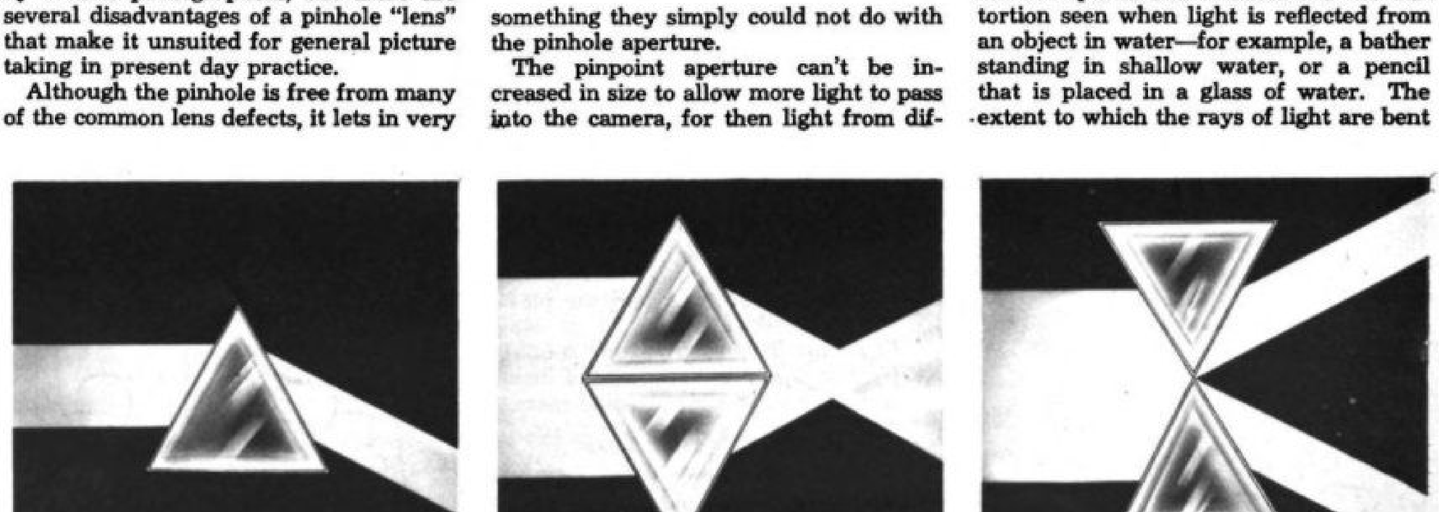
Light is bent as it passes from one medium to another—the basic principle of lens operation. The light-bending ability of glass and water are about the same.

something they simply could not do with the pinhole aperture.

The pinpoint aperture can't be increased in size to allow more light to pass into the camera, for then light from different points in the subject would not be directed to the proper point on the film. Therefore, the images of separate points would overlap and result in an indistinct and unsharp picture. Thus came the need for a lens that would admit more light than the pinhole and produce a sharp image. In its simplest form, a lens is just a specially shaped piece of transparent light-bending material, suited for the job of gathering the rays of light and bringing them together in focus at one plane in the camera—at the position occupied by the film.

How does a lens gather light? This is accomplished by an optical phenomenon of fundamental importance, known as *refraction*. Refraction, or the light-bending property of glass, is by no means a modern discovery. In the ruins of Assyria large pieces of lens-shaped glass have been found which were believed to have been placed in the roofs of houses to help light the interiors. Even the ancient Egyptians had made a crude glass, and crystals were used as burning glasses to light fires long before photography was discovered.

Refraction is nothing more than the bending or change in direction of a beam of light as it passes from one transparent medium to another of different density. An example of this refraction is the distortion seen when light is reflected from an object in water—for example, a bather standing in shallow water, or a pencil that is placed in a glass of water. The extent to which the rays of light are bent



The easiest way to see how simple lenses work is to regard them as combinations of prisms. These pictures, taken in a smoke-filled chamber, show how a light ray is bent from its course by a single prism; two prisms, base to base, gather light, as does a positive lens; when they are placed apex to apex, they diverge or scatter the light rays the same as does a negative lens.

is determined by the difference between the density of glass, water, etc., and that of air. Expressed numerically, this difference is termed the *index of refraction.*

Now refraction all by itself, or the mere uncontrolled bending of light rays, is not enough to produce an image of a subject at the focal plane, which in the camera is the surface of the film or the groundglass. If the bending of light rays alone were sufficient to fulfill the requirements, then one might suppose that it would be possible to use a plain piece of window glass for a lens. However, the light must not only be bent, but it must be further controlled to bring the rays to a focus on the film. This is accomplished by curving the surfaces of the lens so that the light rays entering the outer edges of the lens are bent more than those coming in through the center.

It is easy to see why it is necessary to bend the rays of light more at the edges than the center of a lens, by showing how the rays of light are refracted or bent as they pass through a simple triangular prism. Because the sides of the prism are not parallel to each other, the emerging ray is bent downward and does not continue on in a direction parallel to that in which it entered, as would be the case if a piece of plain glass were substituted for the prism.

An easy, if elementary, understanding of lens operation is gained by considering a lens as a combination of prisms. That's all there is to it. A simple positive lens is actually nothing more than a slightly altered figure of two prisms placed base to base. When two prisms are placed apex to apex the similarity to a simple negative lens can be readily seen.

Thus lenses may be divided into two separate classifications: POSITIVE or converging lenses which collect light rays and NEGATIVE or diverging lenses which scatter the light. An easy way to distinguish between the two types of lenses is to remember that a positive lens is thicker in the center than it is toward the margin, as in a simple magnifying glass or an ordinary flashlight lens. On the other hand, the negative lenses, exemplified by the common type of reducing glass, are thinner in the center than they are at the edges.

Opticians have special terms to describe the many possible variations in the shape of these simple lenses, and when several are combined in a more complicated type of lens they are known as *lens elements* or *components.* These optical terms, descriptive of the simple lens, are for the most part combinations of a few descriptive words: *plano,* which means flat; *concave,* meaning curved inward; and *convex,* meaning curved outward. A *biconcave* lens would be, therefore, one which had two concave sides, while a *convexo-concave* element would have one side which was curved out and the other curved in. Thus, in proper terminology, the common box camera lens is described as a convexo-concave lens, or as a *meniscus* lens, the term "meniscus" merely designating the crescent shape of its cross-section.

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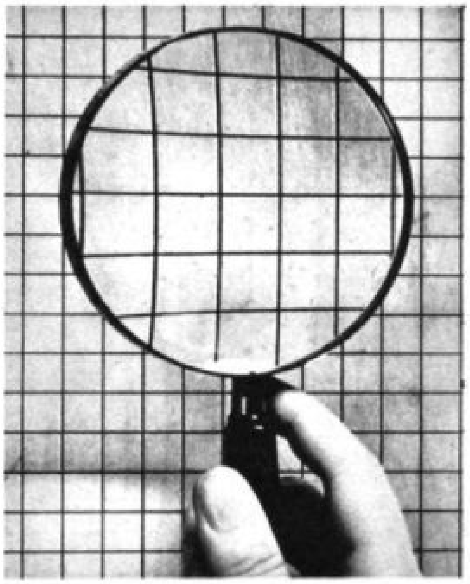
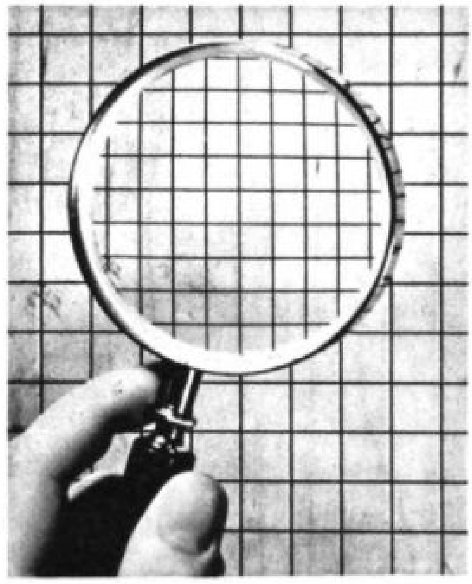


The magnifying or "burning" glass, with its two convex surfaces, is a practical application of the simple positive lens.



The reducing glass, a negative lens with concave surfaces, enables one to see how art work will look when reproduced smaller.

Picture taken with a magnifying glass used as the camera lens. Unsharpness is result of a combination of lens defects.

Addition of a cardboard diaphragm has same effect as stopping down a camera lens. Picture is sharper and depth greater.

Barrel distortion, shown by lettering, results from a positive lens with one flat surface, with convex side toward the film.

Pincushion distortion results when the same plano-convex lens is reversed, with its flat surface facing toward the film.

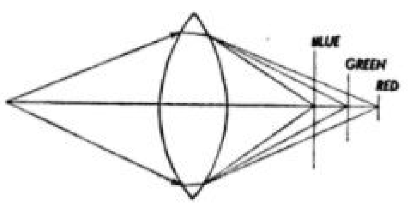
Your Camera Lens and How It Works

(Continued from page 33)

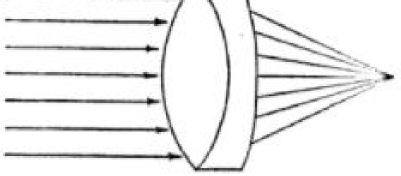
Of all the simpler types of lens used in photography the positive meniscus is perhaps the most common and produces the best image quality for the less demanding photographic enthusiast.

Briefly, the simple meniscus lacks the quality of the higher priced photographic objective lenses, because the image is not critically sharp and may be somewhat distorted in shape toward the edges of the picture. However, faithful reproduction of the subject is essential for certain work, such as in copying, enlarging, or more exacting picture taking. Consequently, the various lens manufacturers have endeavored to reduce defects in lens performance to a minimum. This is accomplished by using lenses which are composed of two or more elements. These are known as multi-element lenses or *objectives*. The use of two or more elements makes possible objectives composed of different types of optical glass. There are literally dozens of different kinds of this special glass available, each with its own properties or individual light-bending characteristics and costing perhaps as much as 300 times the "pop-bottle" variety.

These various types of glass can be combined in an optical system to produce an objective with any of a great many predetermined desirable characteristics. This is where lenses begin to get interesting, for lens manufacture is an exacting science. This was not always true, as the early lenses were made with little



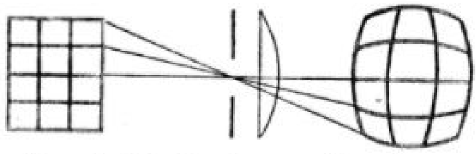
Chromatic aberration. A single-element lens can't focus all colors in one plane.



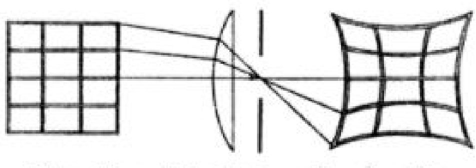
Two kinds of optical glass combined will partially correct chromatic aberration.

knowledge of lens requirements. Now the computations necessary in designating a modern multi-element objective may require many months of laborious work by several experts, even before the job of grinding begins! Progress in lens making during the past century has been great, and some of the lenses produced today are marvels of human skill.

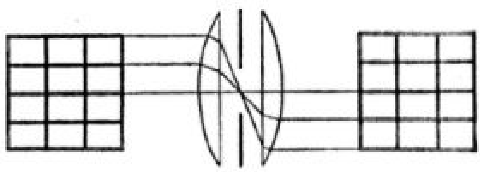
Let's take one of the problems that has to be overcome. If the lens defect known as *chromatic aberration* is present in an optical system, it focuses different colors in front or behind one another, requiring a slight adjustment in focus to make any particular color "sharp." Since it is naturally impossible to focus separately for all the colors in the scene when a picture is being taken, this defect of the differently focused col-



Barrel distortion is caused by plano-convex lens, convex surface toward film.



Pincushion distortion results when the flat surface of plano-convex faces film.



These two faults are overcome by using two similar lenses in the manner shown.

ors interferes with the definition or sharpness of the picture. Therefore, it is naturally desirable to find a way to correct this defect, or to reduce it to a practical minimum. This is particularly true for lenses used in color photography, for otherwise the three images—the red, green, and blue—might be of different sizes and this would lead to color fringes and unsharpness in the final picture.

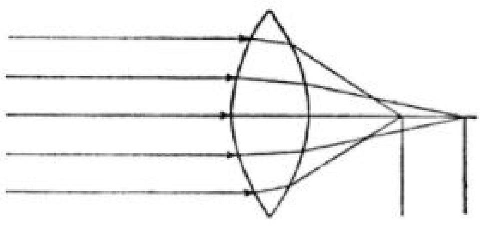
To solve the problems of chromatic aberration, a combination of two different types of optical glass is used, most commonly crown glass and flint glass. Flint glass is the more refractive, with greater light-bending ability than crown glass. Utilizing this property of different types of glass to bring colors to a common focus, the lens manufacturers are now able, without undue difficulty, to produce lenses which are substantially perfect in their ability to bring at least two of the primary colors to a common focus. The simplest form of a color-corrected lens is the so-called landscape lens, known as a single achromat or *meniscus achromat* —even though it is composed of two elements, one of crown and the other of flint glass.

While we're on the subject of lens defects, a few of the more important ones shouldn't escape our attention. Did you ever see a picture in which the objects were distorted in such a way so that they appeared somewhat like the view in a sideshow mirror that made you either tall and thin or short and wide? Undoubtedly the lens used to take the picture was suffering from one of the common defects known as *pincushion distortion* or *barrel distortion*, depending upon whether the vertical and horizontal lines toward the margins of the picture were bowed in or out.

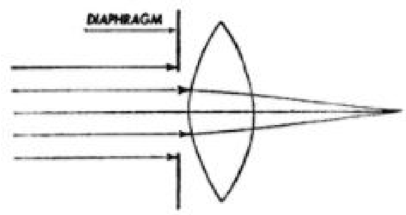
These terms are particularly descriptive of the defect, as in barrel distortion straight lines appear curved like the sides of a barrel, while the term pincushion derives its name from the pincushion shape which the distortion introduces. How to remedy this situation? That's easy for the lens doctors. They know that a single lens without distortion cannot be made, but by combining two or more lenses, with the camera diaphragm placed in the correct position, the distortion may be eliminated completely.

Here's another defect. Did you ever see a picture that was sharper in the middle than it was at the edges? It was probably the result of a common lens characteristic known as *curvature of field*. This high-sounding term merely means that the image of a flat object such as the side of a building formed by a lens which has this defect, cannot be recorded satisfactorily on a flat piece of film. This lens defect is overcome to a considerable degree by cameras designed to hold the film in a curved rather than a flat position, so that the center of the film is farther from the lens than are the edges. An example of this type of design may be found in improved modern box cameras.

Curvature of field, such as that given by a simple converging meniscus lens, can be corrected to some extent by "stopping down" the lens diaphragm so that the marginal rays, which have a longer focus than the central ones, will be eliminated, thus giving pictures formed by the central rays only. In expensive lenses, curvature of field is corrected by



Curvature of field results when marginal rays are bent more than center rays.



A diaphragm eliminates the marginal rays and the resulting image is sharper.

combining the positive lens component with a comparatively weak negative lens having a different index of refraction. Notice the word "weak" was used to describe the negative lens, as naturally there must be more convergence or light gathering than light scattering if the lens system is to form a suitable image.

In the article to follow we will discuss certain lens characteristics that can be put to practical use in making better pictures.

SOME SIMPLE FACTS ABOUT YOUR CAMERA LENS AND HOW IT WORKS PART TWO

By DON D. NIBBELINK, A.R.P.S., A.P.S.A.

IN THE first part of this article we discussed the basic principles of lens operation and some of the faults encountered in simple objectives. Let us now investigate the various characteristics of the camera's lens, and see how we can make use of them in picture taking.

The Lens Diaphragm

The lens diaphragm has functions of primary importance quite aside from its action in respect to control of lens defects. The diaphragm governs the amount of light that enters the lens, and this, together with adjustment of the shutter, controls exposure. Varying the diaphragm opening also changes the depth of field, or the zone throughout which objects before the camera are in acceptably sharp focus. Changes in the size of the lens opening are accomplished by means of either a series of fixed openings of different sizes in a strip of metal which can be slid past the lens (as in some box cameras), or by a variable "iris" diaphragm, so-called because of its resemblance to the iris of the eye.

The diaphragm is similar in effect to a window shade. It allows much light to pass when wide open, and cuts off much of the light when partially closed or "stopped down." It is because the imperfectly directed marginal rays are eliminated with a small aperture, that there is a reduction in the amount of light reaching the film and an increase in the depth of field. This explains why it is necessary to focus accurately when the "fast" lenses are used "wide open," or at large apertures.

Lens Speed

The *speed* of a lens is the lens characteristic most frequently discussed, and is usually the first subject of inquiry when one of the better types of cameras is being purchased. It is commonly expressed in terms of its largest aperture in relation to its focal length, as explained more fully in the next section. Thus, of two lenses with the same focal length, the one with the greater relative aperture gathers more light and produces a more brilliant image than does the "slower" lens. Fast lenses have their greatest value in picture taking under poor light conditions, or in normal light when extremely short exposures are necessary.

The "f" System

The speed of a lens, or the brightness of the image it will produce, is usually measured by the *f* system. This system affords a convenient method of assigning a stop opening or number which may be closely approximated by dividing the focal length of the lens by the width of the opening. For example, a lens having a focal length of ten inches and a maximum opening of two inches is said to have a speed of *f* 5 $(10 \div 2 = 5)$. If the opening is decreased or stopped down, to an effective diameter of one inch, the diaphragm would then be set at *f* 10 $(10 \div 1 = 10)$. The smaller the *f* number, the larger the lens opening and the greater the amount of light admitted to the camera. Since the lens settings in the *f* system are relative and therefore independent of the absolute focal length of the lens, a certain *f* - number indicates a given brightness of light transmitted by a lens, regardless of the differences in size of different lenses and cameras.

Focal Length and Focusing

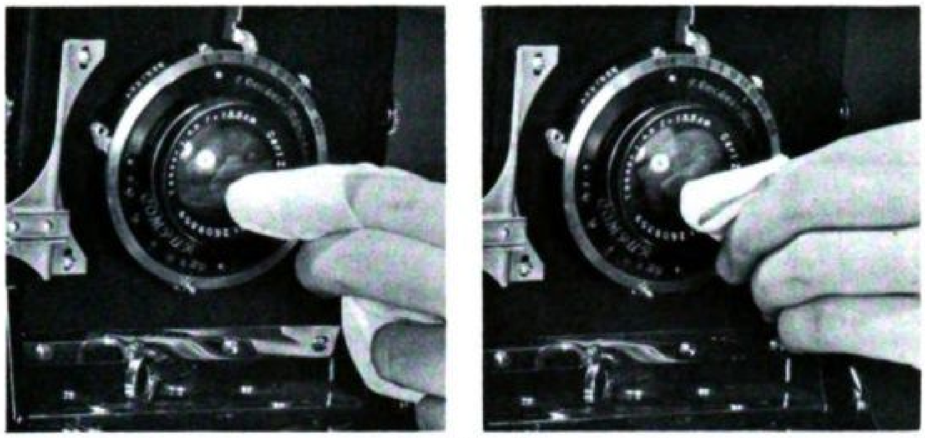
Another important property of a lens is its *focal length*, for ordinarily this de-

Focal length of the lens controls size of the image. This picture was taken with a lens having a focal length of 6 inches.

Image size increases with focal length. This comparative picture was made from the same camera position with a 12½" lens.

termines the size of the picture as well as the distance between the lens and the film. From a practical standpoint, the focal length of most lenses (other than certain telephoto designs) can be considered roughly equal to the distance from the center of the lens to the film or groundglass when a subject at a great distance from the camera is in sharp focus. Of course, this is only a rough-and-ready definition; the precise measurement of focal length is a scientific task.

The plane in which the image or picture is sharply focused by the lens is called the *focal plane,* and this is the position at which the film should be placed in the camera. With simple cameras having inexpensive lenses the distance from the lens to the focal plane is fixed and cannot be adjusted. Such cameras are, therefore, called *fixed-focus,* and of this class the box camera is the most familiar type. With such cameras, all objects not closer than about ten feet are usually in sufficiently sharp focus.



In cleaning a lens, never wipe the surface with coarse material, such as a new linen handkerchief (left). Use lens tissue; it will not scratch the glass (right).

The distance between the nearest and farthest parts of the subject that are pictured sharply is termed the *depth of field.* Occasionally, it is incorrectly called the *depth of focus.* The meanings of these terms are related, but they are by no means the same. Depth of focus is the distance that the film or groundglass can be moved toward or away from the lens while the object remains sharply focused. At the most this may only be measured in small fractions of an inch.

Depth of field refers to the difference between the minimum and maximum distances at which objects before the camera are simultaneously in sufficiently sharp focus when the lens is used at a given diaphragm opening. When lenses are used at wide apertures, the depth of field is less, which means that the image is critically sharp over a smaller range of distances in front of the camera. As mentioned previously, it is therefore necessary to focus very accurately when using cameras with fast lenses opened to their maximum aperture. In some types of cameras, critical focusing is facilitated by a mechanical linking of the lens with an optical rangefinder similar to the giant rangefinders used in modern warfare, so that when two images are superimposed, or a split image made continuous, in the finder, the image will be focused sharply on the film.

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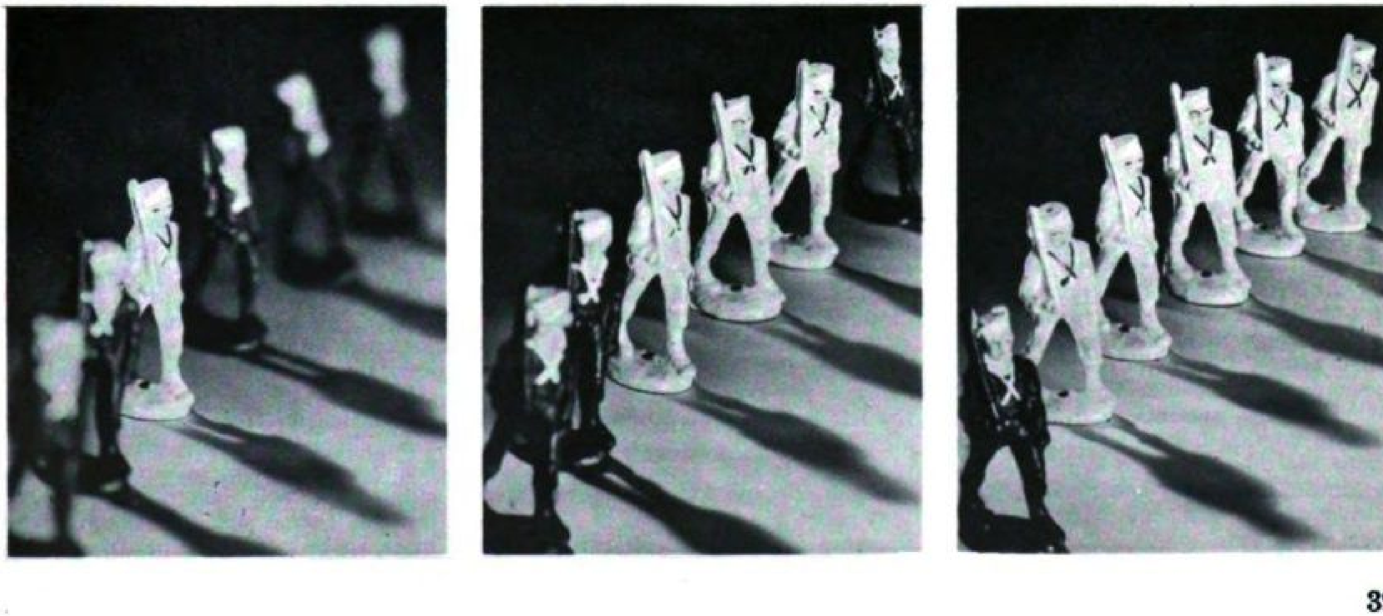
Depth of field is controlled by the lens diaphragm, as demonstrated in this series of pictures. The illustrations above show how the taking lens appeared when it recorded the pictures below. As the size of the aperture decreases, the depth of field increases. White figures indicate those in acceptably sharp focus at *f* 6.3, *f* 16, and *f* 64, respectively.



Your Camera Lens

(*Continued from page 39*)

Aside from variation in the distance between the camera and the subject, the focal length of the lens controls the size of the image. This is easy to remember; if the camera remains at a fixed distance from the subject, the longer the focal length, the larger is the picture on the film; similarly, the shorter the focal length, the smaller the image size.

Lenses of different focal lengths are used for different purposes. For example, with cameras on which various lenses can be used, a lens of short focal length might be chosen when taking pictures of interiors, or when photographing buildings and similar outdoor subjects where a wide angle of view is needed. In fact, such lenses are often referred to as *wide-angle* lenses. A lens becomes a wide-angle lens when it takes in an angle of vision of more than about 55 degrees. One lens with a half-sphere shape and known as the Hill lens, can actually take a picture of the entire sky (180 degrees) on only one negative.

When pictures of very distant objects are to be taken, a lens of long focal length increases the image size, giving a "telephoto" effect as if the camera were nearer the subject than it really is. These long-distance lenses have been used to take infrared pictures of landscapes several hundred miles away from the camera, and are commonly employed for photographing the stars and planets. To effect a compromise between the extremes of a wide-angle picture in which the object seems small and a telephoto picture in which the object is magnified, cameras are most commonly fitted with a lens having a focal length about equal to the diagonal of the picture. For instance, a camera taking pictures of 3¼x4¼ inch size should normally have a lens with a focal length of about 5½ to 6 inches.

The focal length of a lens is also related to the depth of field. Lenses of short focal length have greater depth of field than lenses of long focal length at the same aperture. Depth of field is also less for objects near the camera than for those at greater distances. Consequently, accurate focusing becomes very necessary when using lenses of long focal length or when photographing objects near the camera. With some professional portrait lenses of long focal length the photographer often has difficulty in getting any more than just the eyes in sharp focus. Depth of field is so "shallow" it doesn't include the subject's ears, which are consequently rendered less sharp. This shallow depth of field seldom troubles the miniature camera user, however, except in extreme close-ups of very small objects.

Care of Lenses

The lens usually represents the largest portion of the cost of a better-grade camera, and because lenses are susceptible to damage, they should be handled carefully and given proper protection. When not in use, detachable lenses should be kept in a felt or velvet lined case to protect them against air-borne dirt and dust. Lenses permanently mounted on a camera should be protected by a lens cap when not in use. Lenses should be protected from extremes of temperature, from excessive moisture, and from air containing gases or chemical fumes. If possible, lenses and cameras should be stored at moderate temperatures, away from dampness.

In cleaning a lens the glass surfaces should be wiped carefully with special lens tissue, or with an old, perfectly clean, soft piece of linen. Coarse cloths or materials that have been allowed to pick up dust should never be used, for they may scratch the glass in the lens. Should the lens need recementing, as indicated by loose elements or a cracked or checked appearance, it should be entrusted only to a competent optician or to the manufacturer. Amateur attempts to recement a lens may be ruinous, and even if successful, it is almost certain that the lens elements will be imperfectly aligned, thus introducing imperfections that were originally overcome by the maker only with great skill and effort and at corresponding expense to the purchaser.

Remember that the quality of your pictures is dependent on the quality of your lens. After all, it is the eye of your camera. Treat it as you would your own eye.—