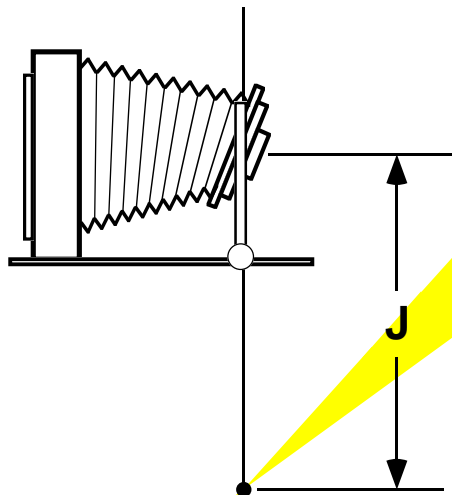


FOCUSING the VIEW CAMERA

*A Scientific Way
to focus
the View Camera
and
Estimate Depth of Field*



by Harold M. Merklinger

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Dedicated to view camera users everywhere.

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The National Aviation Museum, Ottawa

In this photograph, the plane of sharp focus was set to emerge from the ground at the lower edge of the picture, and rise slowly to pass half-way through the hangar.

Preface

I have been active in photography since about 1950, when I was eight or nine years old. Over the past 56 years most of my photography has been done with 35 mm cameras. I have always wanted to pack lots of detail into my pictures, and that yearning has caused me to investigate medium and larger format cameras from time to time. I even owned an 8×10 camera back in the early 1960s—when I couldn't afford to run it. For the most part, however, I have been able to achieve what I intended with 35 mm cameras and slow film, sometimes resorting to 645 or 6×6 format. My previous book, *The INs and OUTs of FOCUS*, explains how to achieve highly detailed images with almost any format.

From time to time, the Graphic Century or Super Technika 23 has been called into action, primarily for the rising front feature. These cameras have a tilting front standard, but it only tips backwards. To achieve a forward lens tilt, one must either suspend the camera upside down, or drop the bed. The inconvenience of that design ensured that I remained largely ignorant of view camera principles for most of my photographic life. Although I knew vaguely of the Scheimpflug Principle, and even tried to use it on occasion, I never really applied it well—or trusted it, for that matter. Was this a reliable photographic tool? Or was this another example of rules like the depth of field “one-third rule” which offers useful advice but lacks rigor.

One of the very first people to buy a copy of *The INs and OUTs of FOCUS* was Raymond Clark, President of ImageQuest Corporation in Colorado. Within a couple of weeks I received a letter from him asking how things work for view cameras when the lens is tilted. I had never attempted to work out the optics of tilted planes before, but here was a challenge. Relatively quickly, I was able to satisfy myself that the Scheimpflug Principle was exact—for thin, rectilinear, flat field lenses. If I could convince myself what the standard ‘correct’ perspective was, I would also be able to describe depth of field for tilted planes. The depth of field went to zero at a strange point in space. One often sees drawings showing the depth of field vanishing where the lens plane, film plane and plane of sharp focus intersect. But in my solution the vanishing point was somewhere else.

The correspondence between Raymond Clark and myself continued, and offered the encouragement I needed to continue the investigation. Eventually, I realized that there was not just one rule at play, but two. The Scheimpflug Principle contains only half of the needed information. A second rule contains the other half. This rule—which I have called the hinge rule in this book—is so simple, it seems unlikely to me that its photographic significance has not

been documented in photography texts. Yes, Theodore Scheimpflug did know about it—it is noted in his British Patent—but it was apparently of less importance to his problem (making maps from oblique aerial photographs) than the rule that bears his name.

Let me be the first to point out that I am not an experienced view camera user. Yes, I have used semi-view cameras for decades, but finding the right amount of lens tilt was more effort than warranted for my purposes. Since uncovering the second rule, however, I have found focusing the view camera to be *less* than twice the work required to focus an ordinary camera. Applying the hinge rule removes all necessity for seemingly endless cycles of tilt and back-focus adjustment. The hinge rule is *more* useful than the Scheimpflug Rule.

The few photographs accompanying this book were taken with an old Burke and James wooden 5×7 view camera equipped with a C. P. Goerz American Optical Co. 9.5 inch Gold Ring Dagor, and with Kodak Tri-X film (not T-Max). All of them were taken at f/22: an aperture 11 millimeters in diameter. I will not claim that these are great works of art. Nor do they constitute particularly tough tests for a view camera. They are, however, relatively typical of the photographs I like to take. What impresses me most about them is how quickly they were taken. On one outing, without even trying to work quickly, I realized in retrospect that I had taken four photographs—all with different focus settings and in two locations—in the space of eight minutes. Without a knowledge of the hinge rule, I think it would have taken me—a novice view camera user—about half an hour each.

Yes, I do feel a bit hesitant, offering a book on a topic of which I am not a master. I can justify it only on the grounds that there is information here that I have been unable to find in any other book. But it is information that has made life very much easier for me, and I hope it will for you also.

And, of course, I wish to thank Raymond Clark for prompting me to undertake this study. Without his encouraging letters, this story might not have been told. Discussions with Phil Davis, John Ward and Craig Bailey have also contributed significantly to this book.

As this is written I still have a few copies of the original *Focusing the View Camera* in stock, but I also have a somewhat modified and expanded version in electronic form that I assembled about five years ago.. The expanded version incorporates the Addendum into the main body of the book and adds other material, much of it from *Shutterbug* magazine articles published after the original book was printed. Version 1.6—the version you are reading now—is a slightly updated of that 5-year-old Version 1.5.

An important addition is the new Chapter 5 on perspective. This is basically a re-packaged version of the article that appeared in the February

1994 issue of *Shutterbug*. There is an important caveat, however. I was never happy with some of the technical terms I used in that article and have struggled to find new language. Specifically, in the *Shutterbug* article I used the term “bore sight” to describe an important (vector) direction for view cameras. Those words better describe a different direction. The term derives from fire arms where the bore sight is simply established by looking down the bore of the gun, from breech to muzzle. The camera equivalent is probably looking through the center of the lens with one’s eye positioned in the geometric center of the ground view camera glass screen. To actually do this would, of course require a hole in the ground glass and the removal of the lens components leaving only the diaphragm. At the risk of confusing the readers of that earlier article, I have changed the meaning of “bore sight” to mean precisely what I have just described. The original direction I used that term for, I have relabeled the “principal axis” of the camera. Please note that this is the principal axis of the *camera*, not the lens. This principal axis is established primarily by the orientation of the film, or electronic image sensor. It is the principal axis that determines the apparent perspective of the image. I am told that, in the usual language of perspective, what I am calling the principal axis is normally termed “the line of vision”.

For a ‘normal’ camera, that is for a camera that has its lens axis perpendicular to the film and centered on the image, the principal axis of the camera, the axis of the lens and the bore sight all coincide. This coincidence of important axes simplifies the associated optical physics considerably. This coincidence is an assumption that underlies nearly all descriptions of photographic optics that I have seen. For view cameras, where it cannot be assumed that these three axes coincide, the mathematics unfortunately gets rather complex. Yet the fundamental principles are still relatively simple, and are within the grasp of all of us to understand. Essentially, the Scheimpflug rule and the hinge rule explain everything; add one extra consideration and depth-of-field is explained also.

In order to assist people visualize the Scheimpflug and hinge rules, I generated a few animated computer “movie” files. These files can be found on my web site: <http://www.trenholm.org/hmmerk/HMbook18.html>.

I would also like to acknowledge that in spite of my best intent, I have realized that I did make one or two unintended mathematical approximations (in both books) concerning depth of field and perhaps should correct some of the formulae and tables, but the errors introduced are so minor that these corrections are really of academic interest only. I worry that that to make the corrections would be to convey the wrong message: the whole concept of depth of field is an approximation. If we really want to be super-precise there are many more optical phenomena we should consider in addition. How precisely do we know the actual aperture, focal length and distance to the point of focus etc? The truth is there are lots of factors we don’t really know or need to know all that precisely.

I once had a lens instruction book that provided depth of field tables to six-figure accuracy. Can you imagine using your cell-phone to call up your model positioned a mile away from the camera and say “You and that mountain are not quite both in focus. Would you move a sixteenth of an inch further back, please!” That’s what six-figure accuracy implies. The transition from “in-focus” to “out-of-focus” is usually so gradual that we would often be unable to detect a significant change in the state of focus if the distance changed by 25%. In this example, the model could probably move a quarter of a mile without our being able to detect a change in effective image sharpness.

A question some people are bound to ask is, “Does all this still apply for digital cameras?” The answer is an unqualified “yes”. Adjustable view cameras will continue to exist in the age of the electronic camera. We may all end up looking at electronic display screens rather than ground glass screens, but the adjustable ‘tilt and shift’ camera will still have its place for high quality photography. I expect that the most common formats—sizes of film or electronic sensors—will be smaller than the typical four by five inches, and typical lens focal lengths will decrease as a result, but the highly adjustable camera will endure. I expect clear advantages will arise out of improved sensor flatness—no more film sag or pop—and better viewing conditions: a brighter, right-way-around view even with stopped down lenses. There may even be a few built-in calculators to help us set-up the camera.

There will, nevertheless, continue to be a place for “art’ and individual judgement is setting up the camera. Perhaps the most common question I am asked is something like this: “OK, you have shown me how to figure out the lens tilt I need if I know where to put the Plane of Sharp Focus, but how do I know where to put the Plane of Sharp Focus?” Sometimes there is a simple answer, but it depends upon many aspects of the situation and the intent of the photographer. I don’t pretend to tell you where to point the camera either, or when to trigger the shutter. That’s all part of the art of photography. There will be situations where tilt and shift are of no value whatever, and there will be others where there are multiple options for obtaining a satisfactory image. Making those decisions requires experience and judgement. I’m only trying to give you tools that I hope will make it easy for you to set up the camera once those decisions are made.

Harold M. Merklinger
29 December, 2006.

Chapter 1

INTRODUCTION

What makes the view camera special is the ability to tilt, shift and swing both the lens and the film. These adjustments permit the camera to take very high quality photographs, that would not be possible any other way. The great flexibility of the camera requires, however, that the photographer understand something of the optical principles that allow the camera to achieve the desired result. The purpose of this book is to help users of view cameras ‘set up’ for their pictures—at least so far as focus and depth of field are concerned.

The book starts with a quick overview of the method. In the ‘Getting Started’ chapter we’ll skip over many of the details. To fully understand the method, however, will take some careful attention. A number of definitions are necessary to ensure that you the user, and I the author, are speaking the same language. Once we understand the words, we move on to a description of the basic optical principles of view cameras. Not all of the terms I use will be familiar to you. A key part of the story is a rule which I have not seen described elsewhere. I call it the Hinge Rule. Like the Scheimpflug principle, the hinge rule states that three planes must intersect along a common line. Two of the three planes, however, have not received much attention in the past.

The emphasis here will be on the ‘bottom line’. For the most part, I will not attempt to prove the physics or the mathematics here; I leave that for another book and another day.

I am not a fan of tables; I have almost never consulted depth-of-field or other tables when using ordinary cameras. (I will use the term ‘ordinary’ camera to describe a camera that lacks back and lens movements other than focus. I will use the term ‘normal’ camera to describe one lacking movements other than focus and shift.) The tables in this book began life as tools to illustrate the optical principles applicable to view cameras. Somewhat to my surprise, I found that I consulted the tables more and more when actually taking pictures. They considerably reduced the time I spent setting up the camera. In time, view cameras will be fitted with scales and indicators which will eliminate the need for these tables. For now, however, the only other source of precise help is experience.

With that apology out of the way, I admit that a significant portion of this book is made up of various tables and graphs. These tables and graphs are intended to help you determine the amount of lens tilt required for any given situation. They also enable you to estimate quantitatively, and in advance, where the limits of depth of field will lie.

The tabled limits of depth of field are those based on an assumed standard of required image resolution. This is the traditional depth of field. In *The INs and OUTs of FOCUS*, I described another way to estimate depth of field—based on object field resolution. The ‘object field method’ does not require tables, but does take a new twist when used for view cameras. This second method is covered only briefly.

An example is provided in Chapter 8 to help illustrate how some of the various tables can be used.

I will also have to admit that I have used some trigonometry: mathematical functions like sine, cosine and tangent. This is a natural consequence of allowing parts of the camera to rotate relative to one-another. That is, they change their relative angular relationships. I had difficulty avoiding such mathematical expressions at first, but I found I could indeed solve most of the the relationships exactly without trigonometry if all measurements are made either parallel to or perpendicular to the film plane. The resulting way of looking at the view camera may seem strange, but there is a logic to it, and it does work. If you do not understand trigonometry, don’t worry. The principles are quite understandable without it and the whole reason for resorting to tables is to let you get away from having to work with that sort of mathematics. I include the mathematical results here primarily to permit those who like to program their own calculators or computers do so.

In order to understand the tables fully, it will be necessary to understand the optical principles described in Chapter 4. But if the math is a problem, stop reading that chapter when you get to Equation (1). Better still, read on, but ignore the mathematics. There is a simple way to do just about everything, anyway.

The information and tables in this booklet have allowed me to shorten the time necessary to set up a view camera considerably—by a factor of four or five. This probably just indicates that I’m not all that skillful. I nevertheless hope you too will find that by understanding the “hinge rule”, as well as the Scheimpflug rule, and by using these tables, you will be able to work more quickly and to capture the intended photograph more easily.

Chapter 2

GETTING STARTED

In what follows it will be assumed that the reader possesses some basic familiarity with the view camera. You know what is meant by tilting and swinging the camera back and the lens. You know that tilting the lens relative to the back—or the back relative to the lens—causes the plane of sharp focus, that surface on which the camera is accurately focused, to move out of parallel with the film plane. You may or may not be aware that the Scheimpflug rule states that the film plane, the lens plane and the plane of sharp focus intersect along a common line. If you don't know this rule, that's OK. Contrary to what some might say, I would argue that it is not absolutely necessary to understand the Scheimpflug rule, anyway.

Figure 1 shows a schematic (symbolic) diagram of a normal camera: one with the lens attached in such a way that the lens axis must stay perpendicular to the film. Figure 2 serves to indicate what happens when the lens axis (or the lens plane which is a surface perpendicular to the lens axis) is tilted. The film plane, the lens plane and the plane of sharp focus obey the Scheimpflug rule. You need not concern yourself about it; the laws of physics will make sure that it is obeyed. The general principle is simple: if we tilt one of the three planes relative to any one of the others, the third plane will get tilted too.

In a normal camera, the camera is always focused on a plane that is parallel to the film. The view camera allows the photographer to focus on objects arranged on or near a plane that is not parallel to the film. This

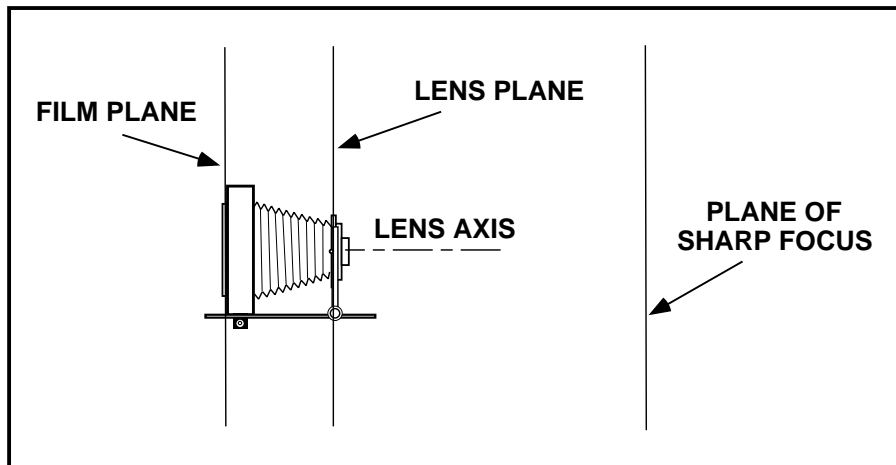


FIGURE 1: *For a 'normal' camera, the film plane, lens plane and plane of sharp focus are parallel to one another.*

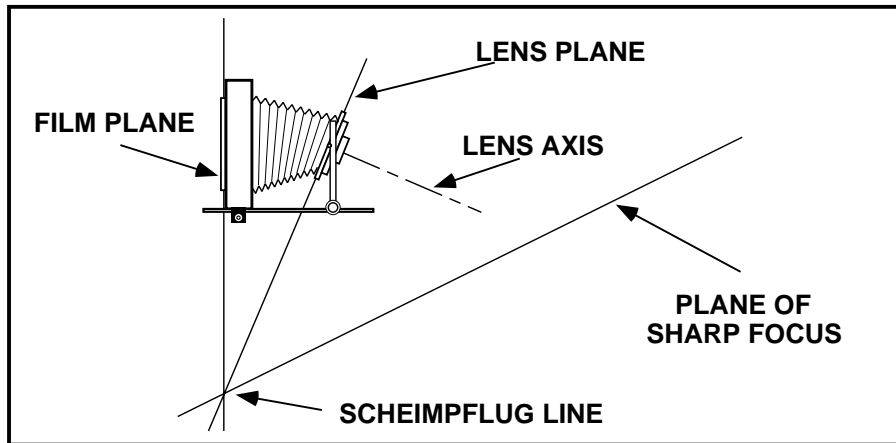


FIGURE 2: *For a view camera, tilting the lens causes the plane of sharp focus to tilt also. The Scheimpflug rule requires that the three planes intersect along one line*

condition is achieved by tilting either the lens or the film relative to the other. That is, we can leave the lens where it is and tilt the back, or we can leave the back where it is and tilt the lens. Or, indeed, we can do a bit of both: tilt both the back and the lens, but not by the same amount in the same direction.

The trouble comes in trying to figure out what to tilt and by how much in order to achieve the intended position for the plane of sharp focus. A further challenge arises when we want to focus on the intended plane of sharp focus *and* maintain correct perspective in the image.

Maintaining correct perspective is perhaps the easier task. Standard perspective usually requires that the film plane remain vertical and more-or-less square to the line of sight of the camera. Sometimes we actually want false perspective in order to make the photograph appear as though it was taken from a place other than the camera's true location. A classic example is taking a picture of a glass-covered water colour painting. If we place the camera squarely in front of the painting, we risk seeing the camera in the final image due to its reflection in the glass. The solution is to move the camera to one side and so view the painting at an angle. This eliminates the reflection. But we also want to make the image look as though the camera had been facing the painting squarely—that is, keep the film and the painting parallel to one another—and let the arrangement of the back and lens effectively squint sideways at the painting. Figure 3 illustrates the resulting arrangement.

If achieving the desired perspective were the only problem, we could get by with lens and back shifts (plus rise and fall) only.

Let's look now at a somewhat more complex situation. We are photographing a painting, but we want to include in the image, not only the painting, but some of the room it is in. Specifically, the large painting is hanging in a church on a wall some 30 feet from the camera. We also want to

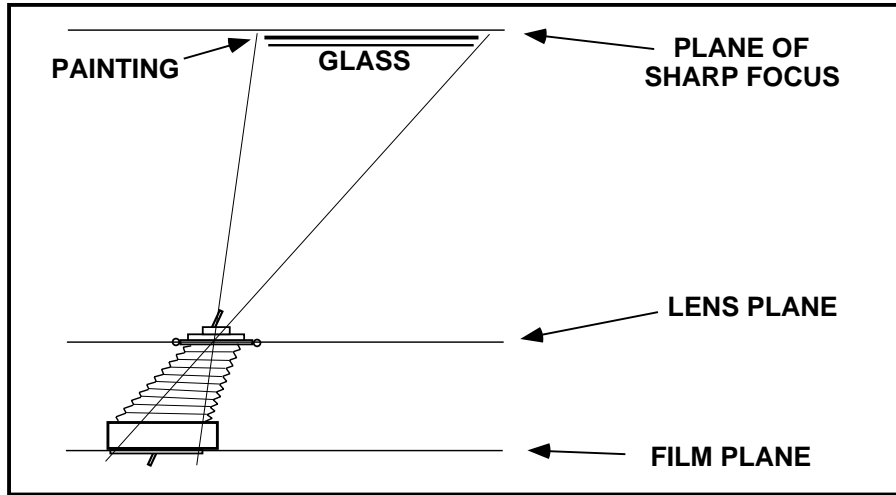


FIGURE 3: The view camera can ‘squint’ sideways, maintaining the proportions of the painting. The final image will look as though it had been taken straight on. Taking the picture as illustrated here avoids seeing a reflection of the camera in the glass.

include a plaque on the church floor indicating where the artist is buried. We want a sharp image of the painting, but also a sharp image of the plaque on the floor some 10 feet from the camera. To ensure both are sharp, we wish the plane of sharp focus to pass through the centers of both the painting and the plaque. Figure 4 illustrates a side view of the problem. To keep the painting rectangular, and the other features of the building in correct perspective, the

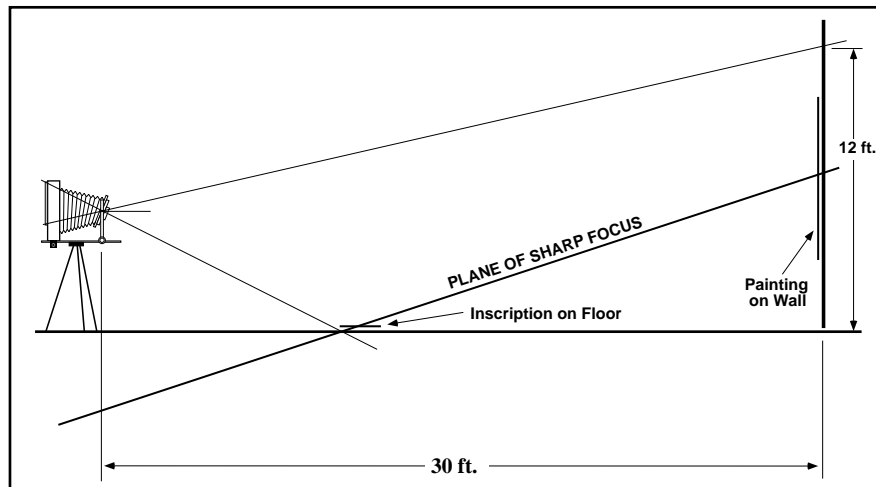


FIGURE 4: Here the task is to adjust the plane of sharp focus so that it passes roughly through the centers of the painting and the inscription. What amount of lens tilt will accomplish this?

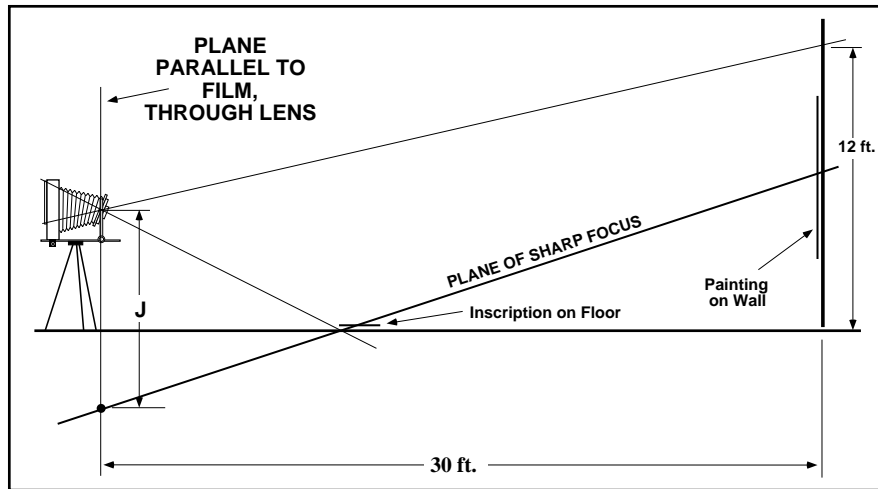


FIGURE 5: *The amount of lens tilt required is set by the special distance **J** and the focal length of the lens. **J** in this case is the height of the lens above the plane of sharp focus.*

camera back must remain vertical and parallel to the painting. And we employ the necessary rise and/or fall to achieve the desired composition. How do we arrange for the plane of sharp focus to fall precisely where we want it to be?

There's another rule that arises from the laws of optics. I call it the hinge rule. The hinge rule will tell us the precise amount of lens tilt needed. The hinge rule is another rule very much like the Scheimpflug principle, but let's skip the details for now. A consequence of the hinge rule is that the required amount of lens tilt is related to only two things: the focal length of the lens, and the distance the lens is from the plane of sharp focus measured in a very special way. We must measure how far the lens is from the plane of sharp focus along a plane through the lens but parallel to the film. In the example at hand, the concept is quite simple. The camera back is vertical. Therefore we measure this special distance in a vertical direction. The special distance is quite simply the height of the lens above the plane of sharp focus, as illustrated in Figure 5. I use the symbol **J** to denote this distance, and the symbol α to denote the amount of lens tilt needed, measured in degrees.

The required amount of lens tilt is given mathematically by this expression:

$$\alpha = \arcsin (f/J).$$

The symbol, **f**, is of course the focal length of the lens. Don't be scared off by the math; it's really quite tame. The arcsine function can be found on many \$15 'scientific' calculators, but we can do even better. Included in this book on page 96 and repeated on a card at the back of this book is a table. The table has columns for lenses of various standard focal lengths. In a column at the left of the table are a number of distances. Find a distance close to that of your distance **J**, and look in that row for the angle listed under the focal length

of your lens. In our example, **J** is equal to 8.5 ft. and the lens in use has a 75mm focal length. The required tilt angle is thus about 1.75°.

For small tilt angles we can even dispense with the table. For lens tilts less than 15°, we can get an approximate value of the lens tilt from either of the following:

if we measure **f** in inches and **J** in feet:

$$\alpha = 5f/J.$$

If we measure **f** in millimeters and **J** in feet:

$$\alpha = f/5J.$$

It's still math, but its pretty simple math.

So we set the lens tilt to 1.75° towards the intended plane of sharp focus. Not all view cameras have tilt scales. My own does not. I use a high school geometry protractor to set the tilt. I can't set it to better than about half a degree, but that's usually good enough.

(The direction of lens tilt will have a bearing on the orientation of the plane of sharp focus. The plane of sharp focus will always be parallel to the lens tilt axis. If we imagine a plane parallel to the film but passing through the lens, that plane will intersect with the plane of sharp focus. If we mark that intersection, we will find it is a line, and it will always be parallel to the axis about which we tilted our lens. In common view camera language, if we use vertical tilt only, the tilt axis is horizontal. If we use swing only, the tilt axis is vertical. If we use both tilt and swing, the matter gets a bit complicated.)

In essence, the hinge rule tells us that if we move the back of the camera to and fro (without changing its angle), closer to or farther from the lens, the plane of sharp focus must pivot on a line a distance **J** from the lens. In our example this pivot line is on the plane of sharp focus directly below the lens. I call that line the hinge line. I call it that because that line is like the pin in a hinge. The plane of sharp focus hinges on that line. As we move the back away from the lens, the plane of sharp focus will swing up in front of the camera. If we move the camera back closer to the lens, the plane of sharp focus will swing down, away from the lens. (It's the Scheimpflug rule working in consort with the hinge rule that causes this rotation, by the way.) So, to achieve the desired focus in our example, we focus, using the ground glass, either on the center of the painting, or on the center of the plaque. If we have done things right, when one is in focus, the other will be too.

That's it; we're done focusing.

But what about depth of field? Well, here the view camera really has the advantage over normal cameras. Calculating view camera depth of field is dead simple. Plainly put, the depth of field at a distance one hyperfocal distance, **H**, in front of the camera is our friend **J**. Like the distance **J** itself, this depth of field is measured in a direction parallel to the film. Either side of

the plane of sharp focus, the depth of field is **J**. In this sense depth of field is symmetrical, always—just so long as we measure it parallel to the film.

Can't remember what the hyperfocal distance is? There's an easy way to remember it. The criterion for image sharpness is often that the circle of confusion at the image should be no greater in diameter than some fraction of the lens focal length. The number often cited is $1/1500$. Well, the hyperfocal distance is then 1500 lens aperture diameters. If our 75 mm lens is set to $f/22$, the hyperfocal distance will be 1500 times 75mm divided by 22. That is about 5100 millimeters or 16.8 feet. There's also a card showing hyperfocal distances for a variety of focal lengths and apertures included with *FOCUSING the VIEW CAMERA*.

It can be demonstrated that the limits of depth of field are also planes, and that they too pass through the hinge line. Getting back to our example, we can now sketch in the limits of depth of field. We know the depth of field at one hyperfocal distance, and we know the limits pass through the hinge line. See Figure 6 for the result. Looks fine: essentially everything included in our photograph is within the limits of depth of field.

The example just described is pretty straight forward. Unfortunately, the photographic situation will not always be quite so easy to analyze. The film will not always be vertical, and the plane of sharp focus will not always be near-horizontal. The basic principles to remember are as follows:

The lens tilt, measured relative to the film plane, determines the distance from the lens to a line about which the plane of sharp focus pivots.

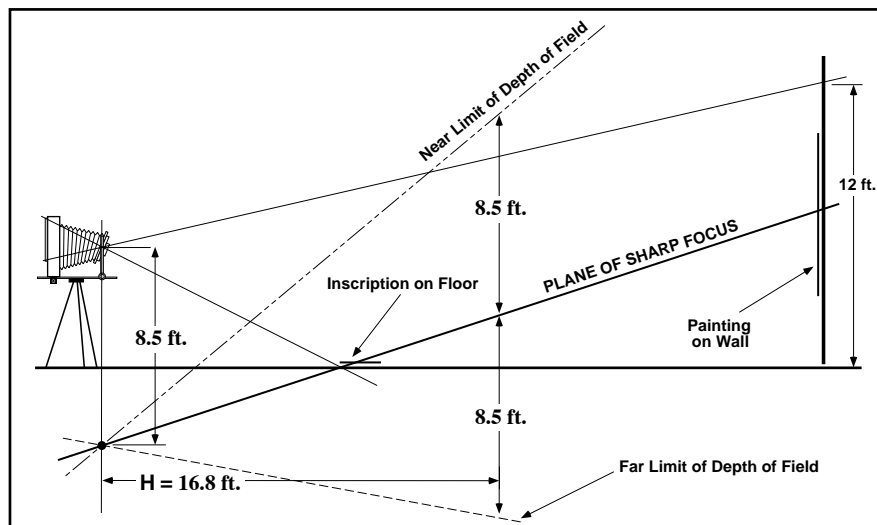


FIGURE 6: Depth of field for view cameras is easy. At a distance of one hyperfocal distance, **H**, the depth of field measured in a direction parallel to the film is simply **J** on either side of the plane of sharp focus. (Camera is not to scale.)

That line, called the hinge line, will also be parallel to the lens tilt axis.

Shortening the distance between lens and film plane causes the plane of sharp focus to rotate (about the hinge line) away from the front of the lens.

Increasing the distance between the film plane and the lens causes the plane of sharp focus to rotate towards the front of the lens.

Depth of field, measured parallel to the film, varies directly as the distance, J . Increasing the lens tilt decreases J and so also decreases depth of field. Depth of field measured this way is always symmetrical about the plane of sharp focus.

Now you have the basics; the rest is just details.

We'll continue with a review of the definitions necessary to analyse the situation more carefully.

Later in this book we'll also discuss how the "object field depth-of-field method" (described in *The INs and OUTs of FOCUS*) applies to view camera situations.



Point Gatineau: Where the Gatineau flows into the Ottawa

In a photograph like this, there is no real necessity for tilts or swings of any kind. But I did, nevertheless, use about one-half degree of forward lens tilt in order to ensure that the plane of sharp focus would pass below the camera. My old wooden camera could easily be half-a-degree out in almost any swing or tilt. Were the plane of sharp focus to lie on the left, right or above the camera, the image would not be uniformly sharp. An enlarged portion of this image, centered on the church, may be seen on page 84.

Chapter 3

DEFINITIONS

This chapter is intended to tell you exactly what I mean by various terms, such as “Parallel-to-Film Lens Plane”. If you are reading this book from start to finish, you need not read closely and remember all these definitions right now. But please do look for the terms you do *not* recognize, and give them a quick read. The purpose of grouping the definitions here is primarily to give you one place to find all the definitions; you won’t have to search through the whole booklet just to find a definition.

Where distances are defined, it is very important to note how the distance is measured. For example, should we measure depth of field along a ray through the lens, or in a direction perpendicular to the plane of sharp focus? There are many ways to measure some of these distances, and how they are measured will affect the answers one obtains. Measuring in certain directions simplifies things, too. I have tried always to measure distances in a way that is photographically meaningful. There’s more than one way to do it, however. If you think it should be done differently, I would appreciate hearing from you.

The definitions that follow are grouped by function. First, we’ll look at the definitions that apply to the lens, then those for the film, and so on. After most definitions is a reference to a figure which should help you understand the definition.

The Lens

Symbol	Name	Definition
— — —	lens axis	The lens axis is an imaginary straight line running through the centers of all the glass elements making up the lens. A lens is virtually always symmetric about its axis; it is in fact a ‘body of revolution’ about its axis. See Figure 7 (overleaf).

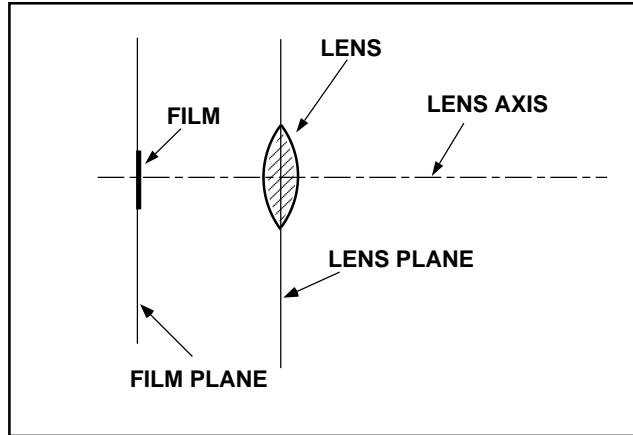
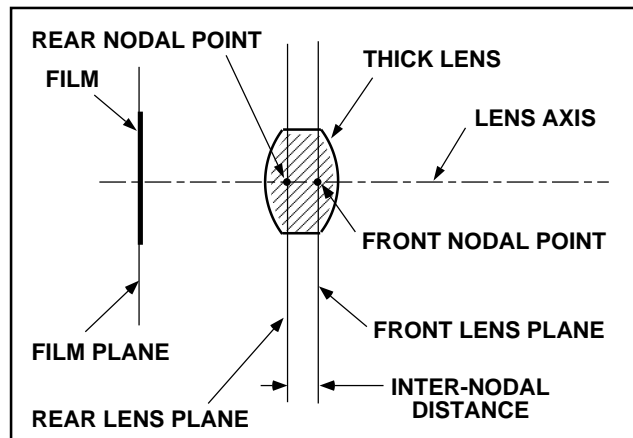


FIGURE 7

FIGURE 8



Symbol	Name	Definition
	lens plane	The lens plane is an imaginary plane passing through the optical center of the lens, and oriented perpendicular to the lens axis. If a lens is optically 'thick', there are actually two lens planes: a front lens plane through the front nodal point of the lens, and a rear lens plane through the rear nodal point. See Figures 7 and 8.
	front nodal point	The front nodal point is the effective optical center of the lens as seen from the front of the lens, that is, the side away from the film. See Figure 8.
	front lens plane	The front lens plane is an imaginary plane through the front nodal point, and perpendicular to the lens axis. See Figure 8.
	rear nodal point	The rear nodal point of a lens is the optical center of the lens as seen from the back side (film side) of the lens. See Figure 8.
	rear lens plane	The rear lens plane is an imaginary plane through the rear nodal point, and perpendicular to the lens axis. See Figure 8.
	inter-nodal distance	The inter-nodal distance is the distance between the front nodal point and the rear nodal point, measured along the lens axis. It can occur that for some lens designs, the front nodal point is actually closer to the film than the rear nodal point. When this happens the inter-nodal distance has a negative value. See Figure 8.

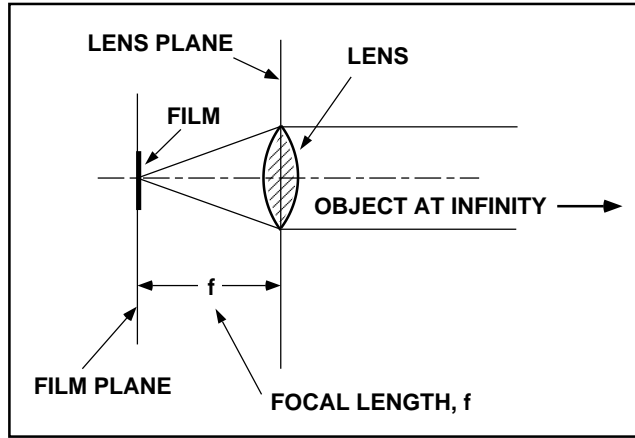


FIGURE 9

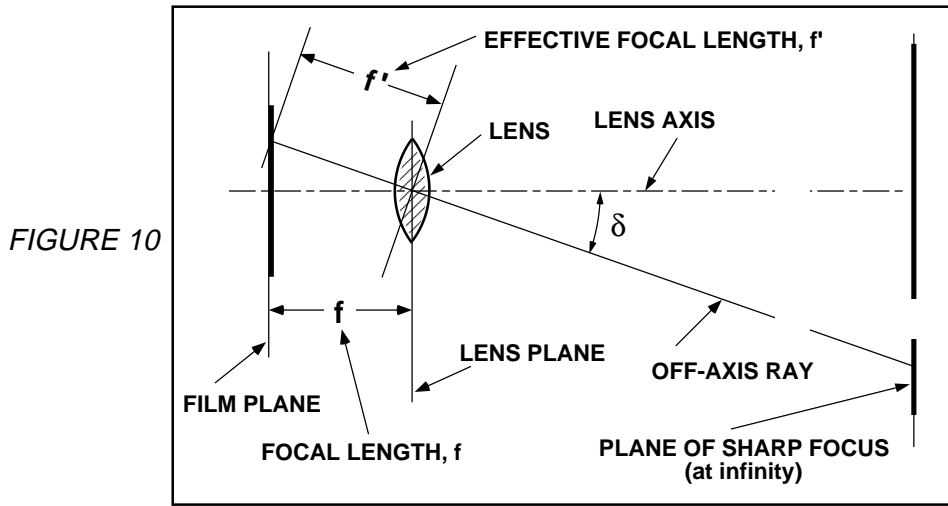


FIGURE 10

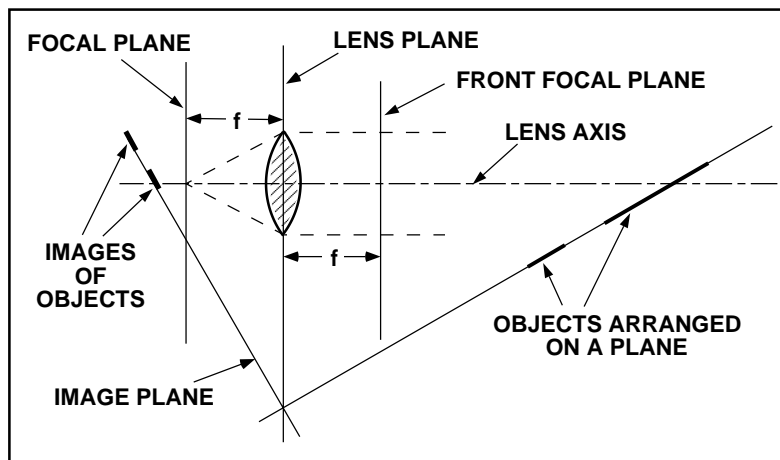


FIGURE 11

Symbol	Name	Definition
	thin lens	A thin lens is one where the inter-nodal distance is very small in relation to its focal length. Many lenses for view cameras, especially those of symmetrical or near-symmetrical design, are optically thin even though the actual thickness of the glass is large. For the sake of simplicity, it will be assumed that lenses are thin, unless otherwise stated.
f	focal length	The focal length of a lens is the distance from the rear nodal point of a lens to the sharp image of a very distant object located in front of the lens but on the lens axis. See Figure 9.
δ	off-axis angle	If an object in front of the lens does not lie on the lens axis, we can describe its position in part through the off-axis angle, δ . δ is the angle between the lens axis and a line from the front nodal point to the object. See Figure 10. (δ is the Greek letter 'Delta'.)
f'	effective focal length	For a distant object not located on the lens axis, the effective focal length, f' , of a lens is greater than its nominal focal length, f . That is, the distance from the rear nodal point of the lens to the sharp image of that object is f' , and f' is greater than f . See Figure 10.
	focal plane	The focal plane of a lens is an imaginary plane parallel to the lens plane (that is, perpendicular to the lens axis) and one focal length behind the rear nodal point of the lens (measured along the lens axis). See Figure 11.

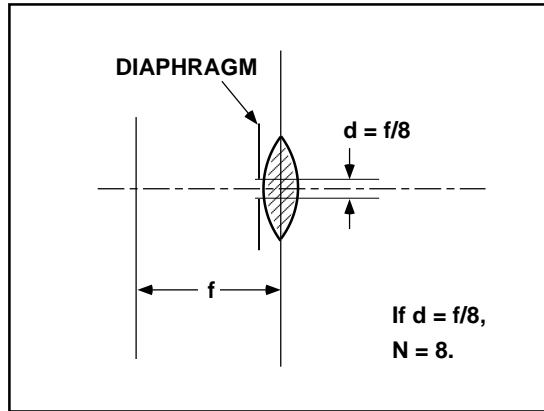
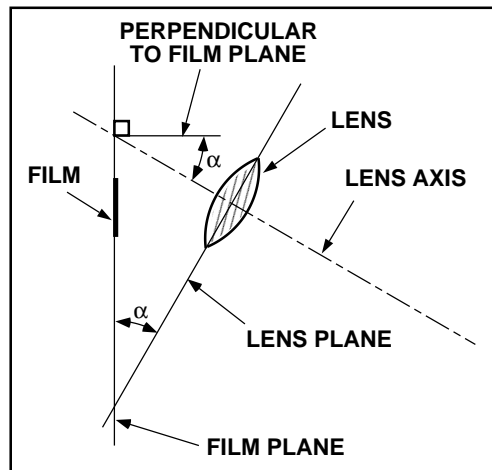
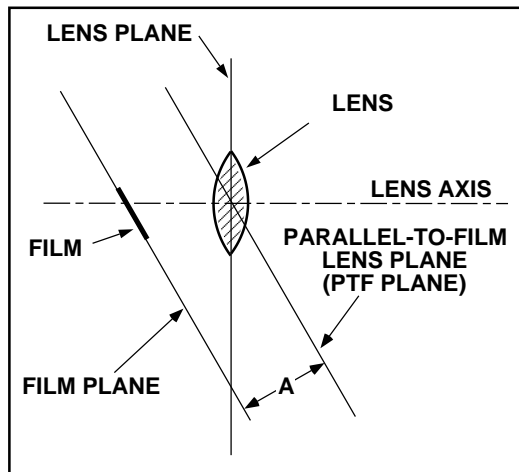


FIGURE 12

FIGURE 13



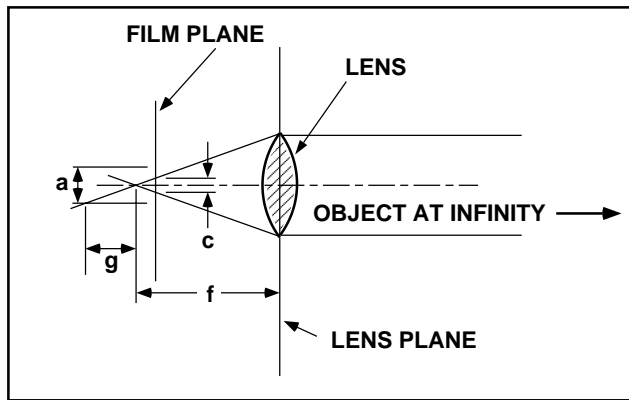
Symbol	Name	Definition
	front focal plane	The front focal plane is an imaginary plane perpendicular to the lens axis and one focal length in front of (away from the film) the front nodal point of the lens. A small object located anywhere on the front focal plane will be focused an infinite distance behind the lens. See Figure 11.
	image plane	Objects arranged on an imaginary plane in front of the lens will be imaged on an imaginary plane, the image plane, behind the lens. The image plane is not necessarily perpendicular to the lens axis. See Figure 11. When the image plane and the film plane coincide, all objects are in focus.
d	lens diameter	A lens normally contains a diaphragm or other “stop” which blocks some of the light that would otherwise pass through the lens. This stop is usually approximately round, and its diameter, as seen from the front of the lens, is called the lens diameter, or working lens diameter. The effective lens diameters as seen from the front, the rear and as measured at the diaphragm may all be different. But what usually matters is the diameter as seen from the front. See Figure 12.
N	f-number	The lens diameter is often described by its size in relation to the focal length of the lens. A lens whose diameter is one-eighth of its focal length is said to be an f-8, often written f/8, lens. In this case the f-number or numerical aperture, N , is equal to 8. See Figure 12.
α	lens tilt	The total effective lens tilt, α , is the angle between the lens axis and a line perpendicular to the film plane. See Figure 13. (α is the Greek letter ‘Alpha’.)

*FIGURE 14*

Symbol	Name	Definition
H	hyperfocal distance	For an ‘ordinary’ or ‘normal’ camera, that is one having no lens tilt, the hyperfocal distance is the distance, measured parallel to the lens axis, from the lens to the inner limit of depth of field, when the lens is focused at infinity. The hyperfocal distance is not strictly a property of the lens or its focal length and numerical aperture. The hyperfocal distance also depends upon the assumed maximum permissible size of the circle of confusion at the film. When a lens is focused at its hyperfocal distance, the depth of field extends from one-half the hyperfocal distance to infinity.
Q	image quality factor	If the maximum permitted diameter of the circle of confusion (a) is equal to the lens focal length, f , divided by Q , the hyperfocal distance is Q times the lens’ working diameter, d .
PTF plane	parallel-to-film lens plane	The parallel-to-film lens plane, or PTF plane, for short, is an imaginary plane through the front nodal point of the lens, and parallel to the film plane. See Figure 14.

The Film and the Image Space

film plane	It is assumed in this book that the film is located on an imaginary plane, called the film plane. The film plane may have any orientation and may lie any distance behind the lens. The film plane is the primary reference plane for the view camera. In general, all other angles are measured with respect to the film plane or with respect to a line perpendicular to the film plane. See Figure 14.
------------	---

*FIGURE 15*

Symbol	Name	Definition
A	lens-to-film distance	Also called the back focus distance, the lens-to-film distance is the distance from the film plane to the rear nodal point of the lens, measured in a direction perpendicular to the film plane. In <i>The INs and OUTs of FOCUS</i> , I used the symbol B to denote the lens-to-image distance. For most purposes in the present book, the symbols A and B may be used interchangeably, since the image is assumed to be sharply focused at the film. It is frequently useful to measure A in focal lengths. The distance A measured in focal lengths is denoted as A/f . See Figure 14.
PTF plane	Parallel-to-film lens plane	The parallel-to-film lens plane, or PTF plane, for short, is an imaginary plane through the front nodal point of the lens, and parallel to the film plane. See Figure 14.
c	diameter of the circle-of-confusion	When the image of a very tiny spot does not lie precisely at the film plane, the image on the film will be a small circle of diameter, c . This circle is called the circle of confusion. See Figure 15.
a	largest permissible diameter for c	For the traditional method for calculating depth of field, it is assumed that there is a largest diameter which may be tolerated for the circle-of-confusion. This largest permissible diameter is denoted as a . See Figure 15.
g	depth of focus	For a stated value of the largest permissible diameter of the circle of confusion, a , and for a lens of numerical aperture, N , the depth of focus is simply equal to the product of N and a : g = Na . In order to be rendered with acceptable resolution, the sharp image must lie within a distance, g , either side of the film plane. See Figure 15.

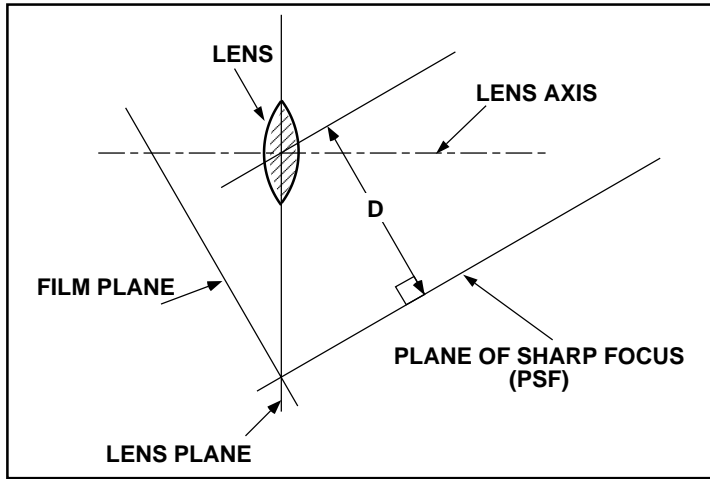


FIGURE 16

FIGURE 17

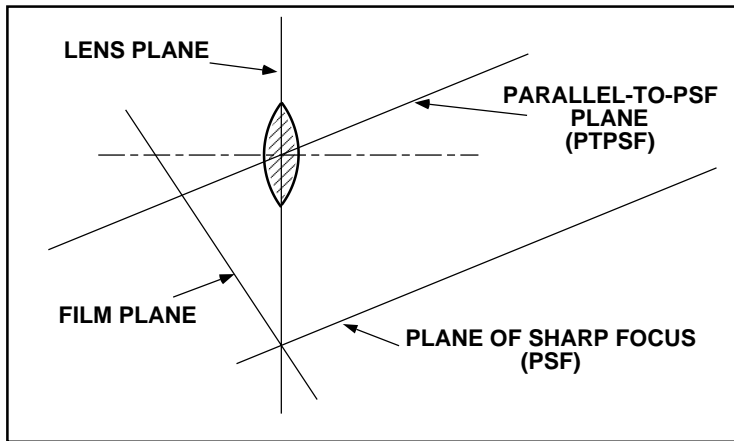
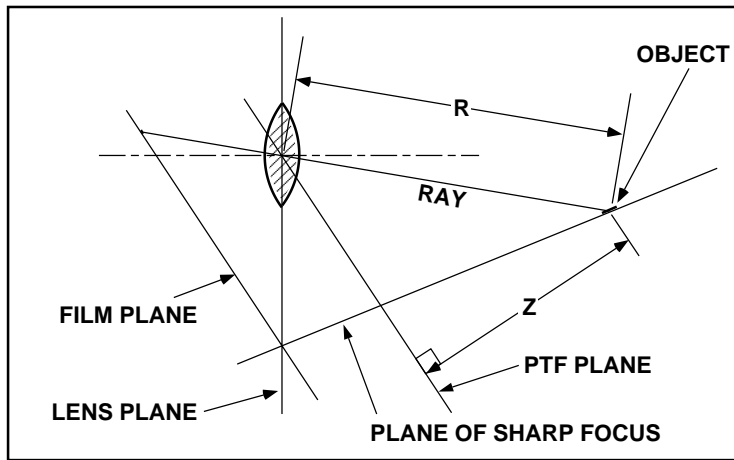


FIGURE 18

Symbol	Name	Definition
The Plane of Sharp Focus and the Object Space		
PSF	plane of sharp focus	The plane of sharp focus is that plane in front of the camera, every point of which is focused precisely on the film plane. Any small object located on the plane of sharp focus is in perfect focus. See Figure 16.
D	lens-to-PSF distance	Distance D is that from the front nodal point to the plane of sharp focus, measured in a direction perpendicular to the plane of sharp focus. D is the shortest distance between the plane of sharp focus and the lens. For some purposes it is useful to measure D in units of one focal length. D/f will be used to denote the distance D measured in this way. See Figure 16.
R	lens-to-object distance	The distance from the lens to some object lying on the plane of sharp focus is denoted as R when the distance is measured simply as the shortest direct line from the object to the front nodal point of the lens. See Figure 17.
Z	lens-to-object distance	The distance from the lens to some object lying on the plane of sharp focus is denoted by Z when the direction of measurement is perpendicular to the film plane. See Figure 17.
PTPSF	parallel-to-PSF lens plane	The parallel-to-plane of sharp focus lens plane is an imaginary plane through the rear nodal point of the lens, parallel to the plane of sharp focus. We will use this term rarely. See Figure 18.

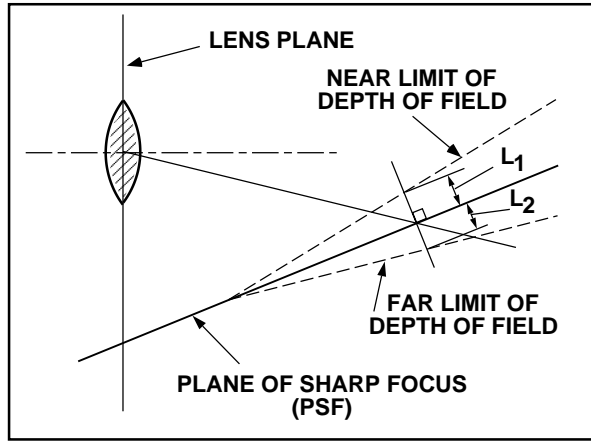


FIGURE 19

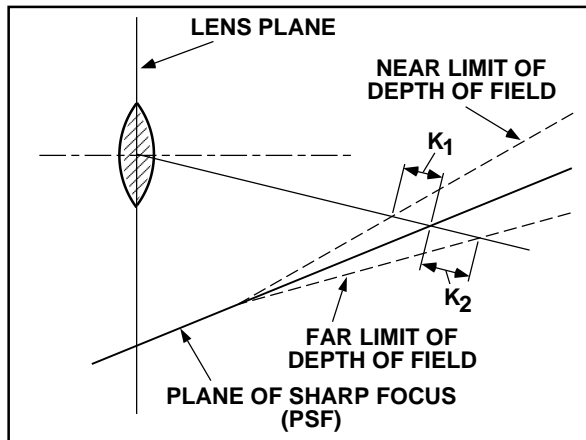


FIGURE 20

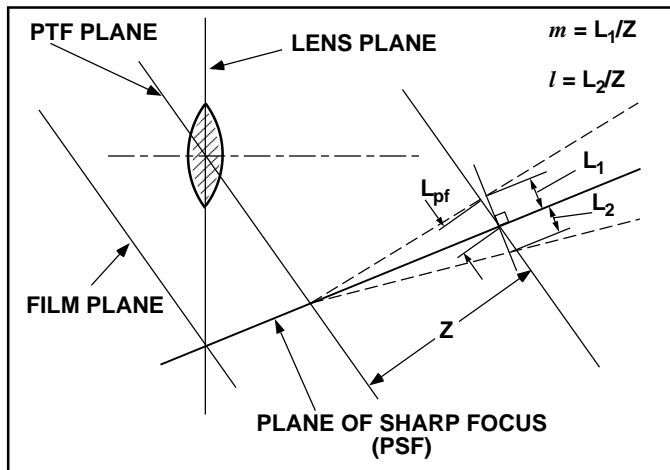


FIGURE 21

Symbol	Name	Definition
L	depth of field	Objects within some distance, L , of the plane of sharp focus will be imaged sharply enough to be considered “in focus”. The depth of field, L , is measured in a direction perpendicular to the plane of sharp focus. Since the depth of field is not necessarily equal on both sides of the plane of sharp focus, we may use L_1 to denote the depth of field on the lens side of the plane of sharp focus, and L_2 to denote depth of field on the far side. See Figure 19.
L_{pf}	depth of field	A variation on ways to describe depth of field is to measure its extent in a direction parallel to the film plane. Such a measure of depth of field is denoted as L_{pf} . See Figure 21.
K	depth of field	Objects within some distance, K , of the plane of sharp focus will be imaged sharply enough to be considered “in focus”. The depth of field denoted by K is measured along a ray from the lens to some specified point on the plane of sharp focus. As for the depth of field, L , we may use K_1 and K_2 to denote the depth of field on the lens side and the far side of the plane of sharp focus respectively. Note that the only difference between L and K is the direction in which the distance is measured. See Figure 20.
m	depth of field fraction	The depth of field, L , may be expressed as a fraction of the distance Z . m is that fraction (or coefficient) applying on the lens side of the plane of sharp focus: $L_1 = mZ$. See Figure 21.
l	depth of field fraction	The depth of field, L , may be expressed as a fraction of the distance Z . l is that fraction (or coefficient) applying on the far side of the plane of sharp focus: $L_2 = lZ$. See Figure 21.

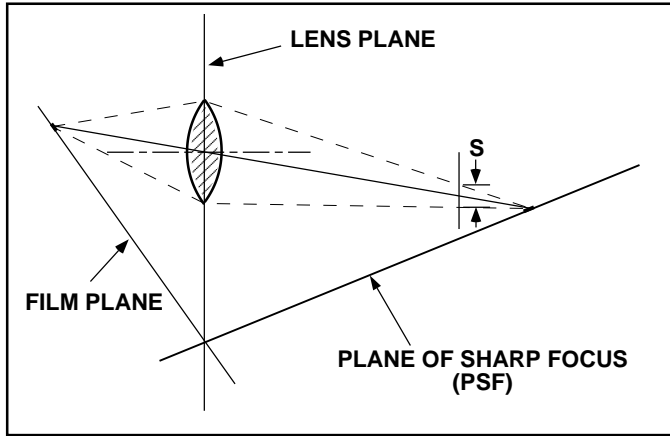


FIGURE 22

FIGURE 23

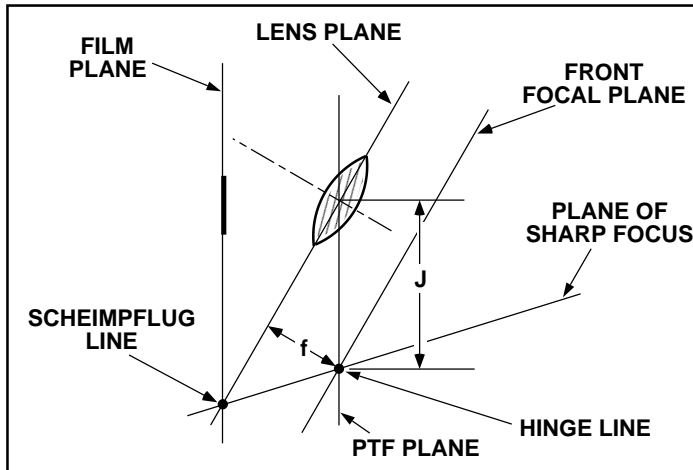
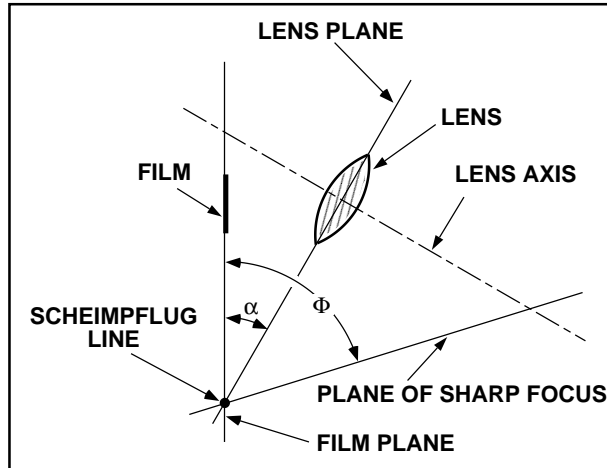


FIGURE 24

Symbol	Name	Definition
S	spot size, or disk of confusion	The spot size, S , is the diameter an object must be in order to be registered at full contrast on the film. If an object is smaller in size than S , it may still show up in the image, larger than it should be, and at reduced contrast. See Figure 22. The spot size, or “ <i>disk-of-confusion</i> ” was discussed at length in <i>The INs and OUTs of FOCUS</i> .
Φ	plane of sharp focus angle	The angle Φ is the angle of the plane of sharp focus, relative to the film plane. See Figure 23. (Φ is the Greek letter ‘Phi’.)
θ	hinge line tilt	The angle θ is the tilt of the hinge line compared to the horizontal plane. θ is measured in the PTF plane. (θ is the Greek letter ‘Theta’.)

Other Terms and Distances

- Scheimpflug line

In order for a view camera image to be sharp, the rules of optics state that the film plane, the lens plane and the plane of sharp focus must intersect along a common line in space. That line is the Scheimpflug line. See Figure 23. Since the Scheimpflug line is seen on end, it is represented in the figure as a dot.
- hinge line

The rules of optics state that for rectilinear, flat-field lenses, the PTF plane, the front focal plane and the plane of sharp focus must intersect along a common line. That line is the hinge line. The hinge line is always parallel to the Scheimpflug line. See Figure 24.

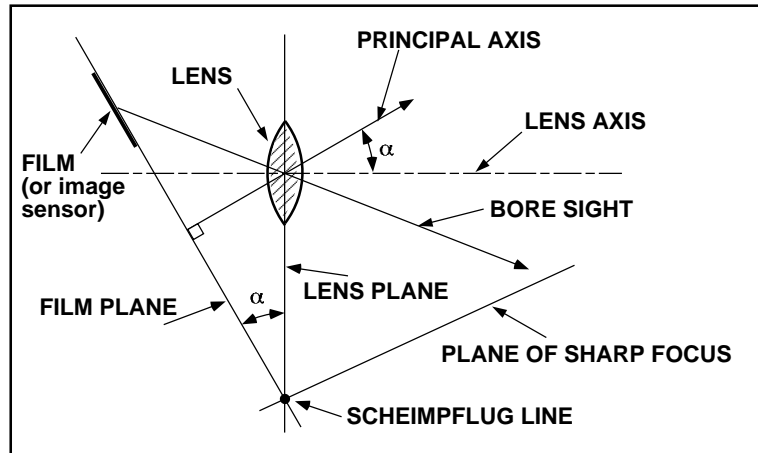


FIGURE 25

Symbol	Name	Definition
J	lens-to-hinge line distance	The distance from the front nodal point of the lens to the hinge line (measured perpendicular to the hinge line) is denoted as J . When forward lens tilt is used, J is effectively the lens height above the plane of sharp focus. See Figure 24 (on page 24).
	principal axis	A line through the lens center, and perpendicular to the film plane is called the principal axis. The angle between the principal axis and the lens axis is the lens tilt, α . See Figure 25 (above).
	bore sight	A line from the geometric center of the image through the center of the lens is here called the bore sight. This is essentially the 'look direction' of the camera. See Figure 25 (above).

Chapter 4

VIEW CAMERA OPTICAL PRINCIPLES

The fundamental optics of ‘normal’ cameras are described by just one rule: the lens equation. ‘Normal’ cameras are those having the lens axis fixed in a direction perpendicular to the film plane. The lens equation relates the lens-to-film distance, **A**, the lens-to-plane of sharp focus distance, **D**, and the focal length, **f**, to one-another. Although the standard lens equation does not apply for off-axis rays, the matter is circumvented by measuring all the distances in a direction perpendicular to the film plane, or parallel to the lens axis—which is the same thing for ‘normal’ cameras. View camera design complicates things by allowing the photographer to tilt or swing the lens and the film plane independently. Distances measured parallel to the lens axis are no longer equivalent to those measured perpendicular to the film plane. To make matters even more complicated, swinging the lens and/or the film, also rotates the plane of sharp focus so that distance measured perpendicular to the plane of sharp focus now presents yet a third way to measure things. Fortunately, we can explain view camera optical principles with just two or three basic rules. Using these rules it is possible to focus the view camera systematically, and to understand depth of field for tilted planes.

We’ll discuss the details of the view camera lens equation itself a little later. Happily, the view camera lens equation can be interpreted in the form of two relatively simple rules that require no understanding of the mathematics. These rules are the Scheimpflug Rule and what I call the Hinge Rule. Together they tell us everything that the view camera lens equation does.

The Scheimpflug rule is well known to many view camera users. This principle states that for thin, flat-field, rectilinear lenses, the film plane, the lens plane and the plane of sharp focus must intersect along a common line. Figure 26 illustrates. The line where all three planes intersect, we’ll call the Scheimpflug line. Since the figure depicts a cross-section through the scene in a direction perpendicular to all three planes, the planes are drawn as straight lines. In three dimensions, the planes would extend out of the paper, at right angles to the page. The Scheimpflug line, which also extends out of the paper, is shown as a simple dot. No matter how the lens and film are tilted and/or swung, it will always be possible to find some direction from which to look at the camera so that it looks something like Figure 26. In this book we use the symbol α to denote the lens tilt relative to the film plane, and Φ to denote the resulting tilt of the plane of sharp focus relative to the film.

For thick lenses, the Scheimpflug rule must be adjusted to account for the inter-nodal distance of the lens. As illustrated in Figure 27, any ray is

assumed to pass from one nodal plane to the other in a direction parallel to the lens axis. The same is true for the extensions of the plane of sharp focus and for the film plane.

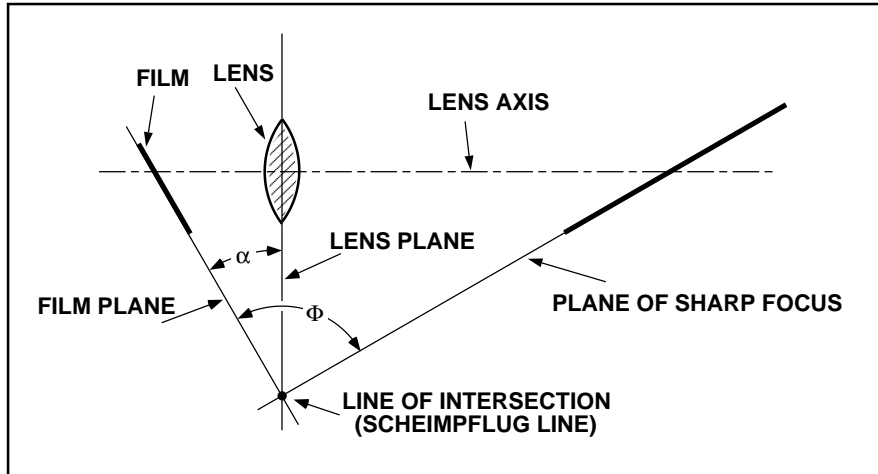


FIGURE 26: *The Scheimpflug Principle states that the Film Plane, the Lens Plane and the Plane of Sharp Focus must intersect along a common line.*

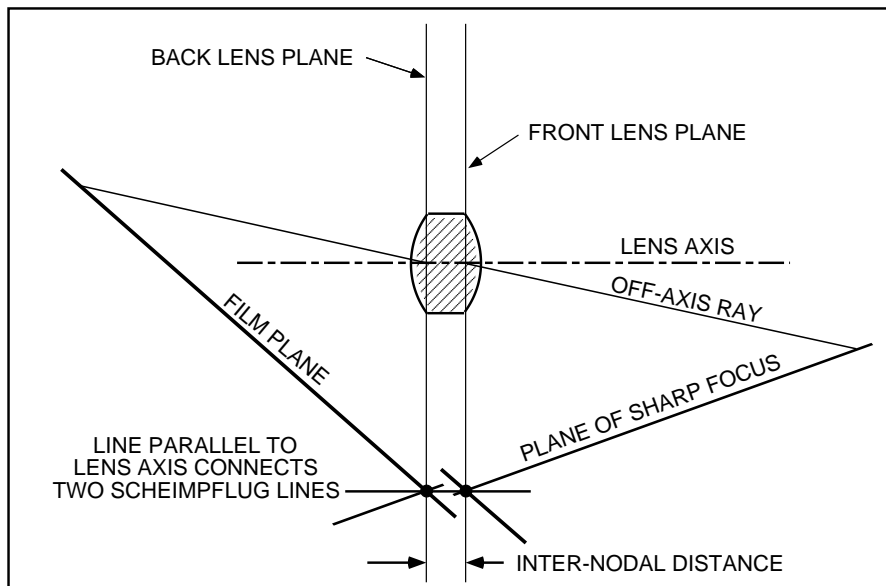


FIGURE 27: *For thick lenses, the Scheimpflug Principle must be adjusted. Any ray or plane which passes through the lens planes, moves from one lens plane to the other in a direction parallel to the lens axis.*

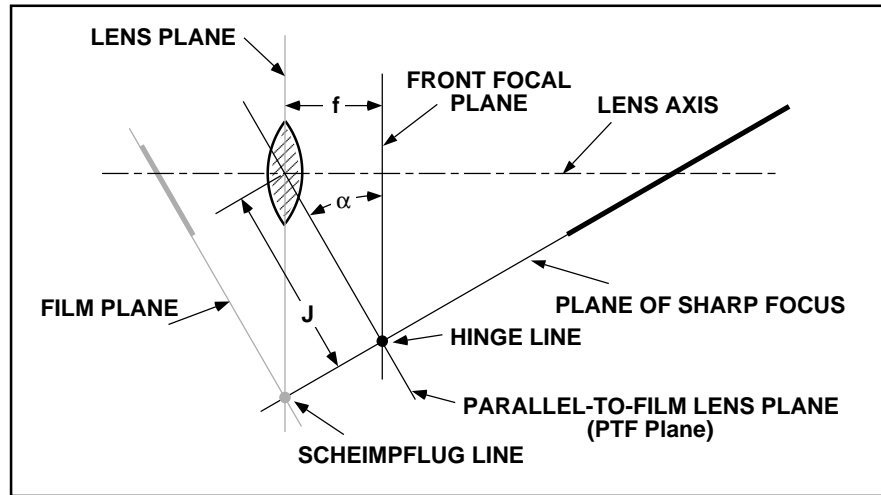


FIGURE 28: *The Hinge Rule states that the Front Focal Plane, the Parallel-to-Film Lens Plane and the Plane of Sharp Focus must also intersect along a common line. J is measured parallel to the PTF Plane.*

The Scheimpflug principle is a necessary condition for the lens equation to be satisfied, but it is not enough. With reference to Figure 26, suppose that the lens and lens plane are swung about the Scheimpflug line, keeping the distance from the lens to the Scheimpflug line constant. We'll also keep the film plane and the plane of sharp focus fixed. If the Scheimpflug rule were enough, the image would stay in focus as we swing the lens. We know from experience that the image does not stay in focus. As the lens moves through the full range, we will find one, two or no places where the image is in focus.

The needed additional information is contained in the hinge rule. This rule states that the parallel-to-film lens plane (PTF plane), the plane of sharp focus (PSF) and the front focal plane must intersect along a common line. This second important line, we'll call the hinge line. This rule is depicted in Figure 28. The hinge rule and the Scheimpflug rule together solve the view camera lens equation for us—no matter where the object and the image lie.

The hinge rule *alone* can help a lot if we know where we wish the plane of sharp focus to be, relative to the lens and film. If we know the desired orientation of the film plane, and how far the lens is from the plane of sharp focus (measured along the PTF plane), we know something else. We know the required lens tilt. We'll call the lens-to-plane of sharp focus distance, measured along the PTF plane, J . When the film plane is oriented vertically, and the lens tilt axis is horizontal, J will represent the height of the lens above the plane of sharp focus.

(Table III on pages 96 and 97 shows several examples the relationship between J and α for a number of common focal lengths. This table gives us

the angle, α , needed for a variety of \mathbf{J} distances for each focal length. Table IV on pages 98 and 99 show similar information in a slightly different form. In Table IV, the distance \mathbf{J} is given for a range of tilt angles.)

If \mathbf{J} is measured in focal lengths, there is just one simple relationship between \mathbf{J} and α :

$$\frac{\mathbf{J}}{f} = \frac{1}{\sin \alpha}. \quad (1a)$$

This may, alternatively, be written as:

$$\alpha = \arcsin \left(\frac{f}{\mathbf{J}} \right). \quad (1b)$$

This expression may be further abbreviated, as shown on page 6 in the *Getting Started* chapter.

If the film is racked to and fro, the Scheimpflug rule and the hinge rule, working together, cause the plane of sharp focus to rotate or pivot about the hinge line (see Figure 29). (For convenience in calculating \mathbf{J}/f , Table V gives the value of \mathbf{J}/f for the same range of \mathbf{J} distances and focal lengths used in Table III.)

In practice, it is generally easiest to first use Table III to determine the required lens tilt or swing, then focus using the camera back to put the plane of

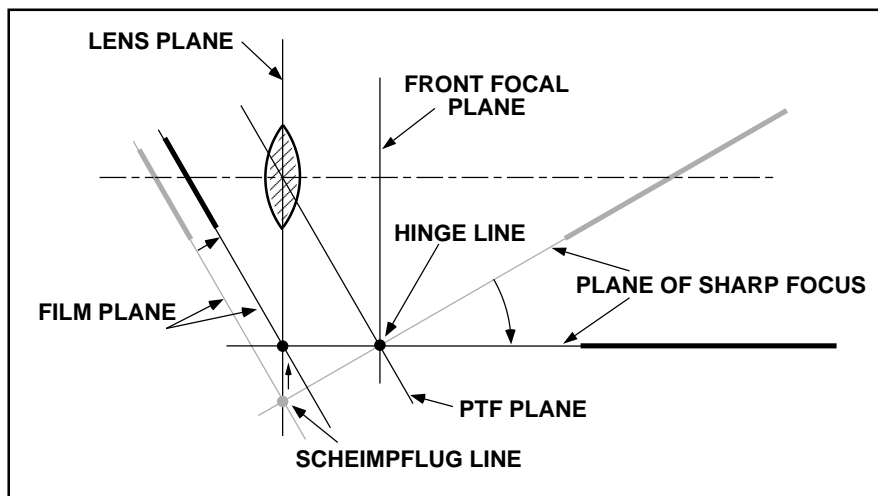


FIGURE 29: *The Hinge Rule, together with the Scheimpflug Rule, requires that if the film is moved closer to the lens, the Plane of Sharp Focus must move away from the lens, rotating about the Hinge Line.*

sharp focus in the desired orientation. Should this not be possible, we can use the following equation to determine the required lens-to-film distance, **A**:

$$\frac{\mathbf{A}}{\mathbf{f}} = (\sin \alpha) \left[\frac{1}{\tan (\Phi - \alpha)} + \frac{1}{\tan \alpha} \right]. \quad (2a)$$

Again, if the lens-to-film distance is expressed in focal lengths, the same graph or table can be used for lenses of all focal lengths. (Table VI shows values of **A/f** for various combinations of normalized distances, **J/f**, and desired plane of sharp focus angles, Φ .) We can also rewrite Equation (2a) to solve for Φ :

$$\Phi = 90^\circ + \arctan \left[\frac{\mathbf{f}}{\mathbf{A} \sin (\alpha)} - \frac{1}{\tan \alpha} \right]. \quad (2b)$$

The relationships between α , Φ , and **A/f** are shown graphically in Figures 62 and 63 on pages 104 and 105.

Returning to the matter of the lens equation, the basic lens equation—the one we usually read about—may be written as:

$$\frac{1}{\mathbf{A}} + \frac{1}{\mathbf{D}} = \frac{1}{\mathbf{f}} \quad (3)$$

where **A** is the lens-to-film distance, **D** is the lens-to-plane of sharp focus distance, and **f** is the focal length of the lens. Note that, for ‘normal’ cameras, distances **A** and **D** are usually assumed to be measured in a direction parallel to

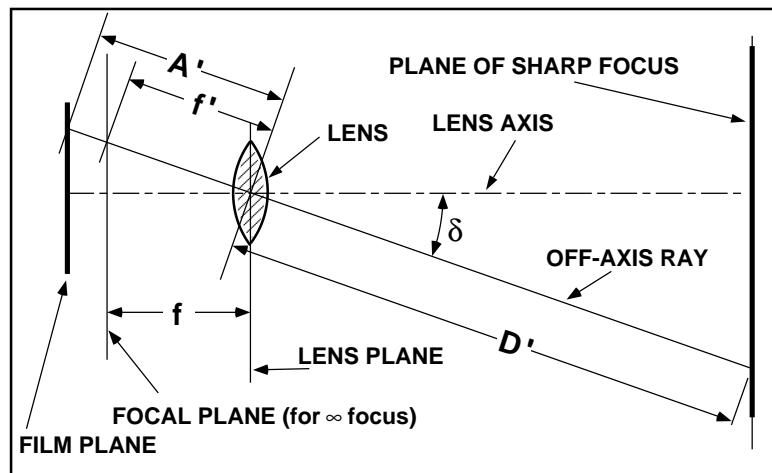


FIGURE 30: The object distance, **D'**, and image distance **A'** are illustrated here for an oblique ray, making angle δ with the lens axis.

the lens axis, or perpendicular to the film plane, or perpendicular to the plane of sharp focus.

The lens equation for *oblique rays*—those not parallel to the lens axis—is given by the following equation:

$$\frac{1}{\mathbf{A}'} + \frac{1}{\mathbf{D}'} = \frac{1}{\mathbf{f}'}, \quad \mathbf{f}' = \frac{\mathbf{f}}{\cos \delta} \quad (4)$$

where δ is the off-axis angle, \mathbf{A}' is the lens-to-film distance measured along the ray, \mathbf{D}' is the lens-to-plane of sharp focus distance measured along the ray, and \mathbf{f}' is the effective focal length of the lens. Figure 30 (on the previous page) illustrates.

A consequence of the lens equation for oblique rays is that the effective focal length of a lens is not a fixed quantity. As a lens is tilted or swung in view camera use, its effective focal length changes. The focal length usually appears to increase as the lens is tilted. The change is negligible for small angles of tilt, but can be quite significant for angles of 25° and more. Table I on page 90 in the Tables section shows the results. The major consequence of this effect is that when a lens is tilted, the camera's angle of view changes. One may discover that when lens tilt or swing is used, a focal length shorter than anticipated is needed to cover the intended angle of view. If the main subject is closer to the lens axis after the lens is tilted or swung than it was with no tilt or swing, however, the effect may seem to go in the opposite direction. The effective focal length may appear to shorten. Moving the lens axis away from the main subject increases effective focal length; moving the lens axis closer to the main subject shortens the effective focal length. The point to be

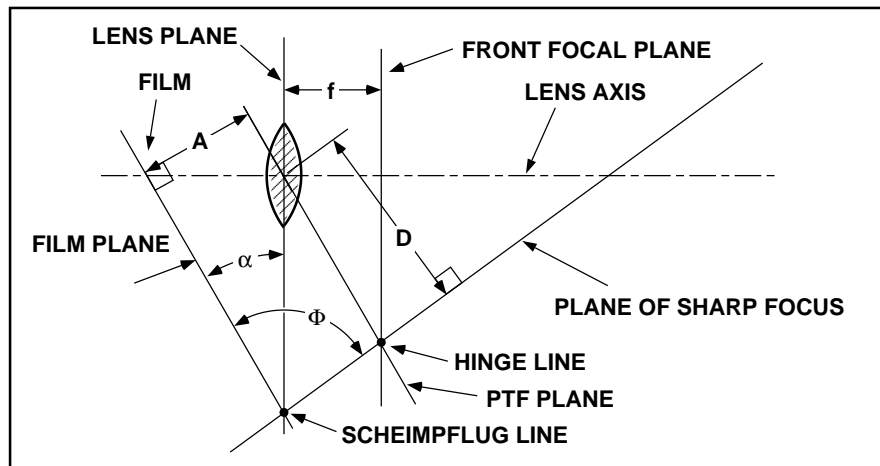


FIGURE 31: The distances and angles important for the view camera lens equation, Equation (5), are illustrated here. \mathbf{D} is measured perpendicular to the Plane of Sharp Focus.

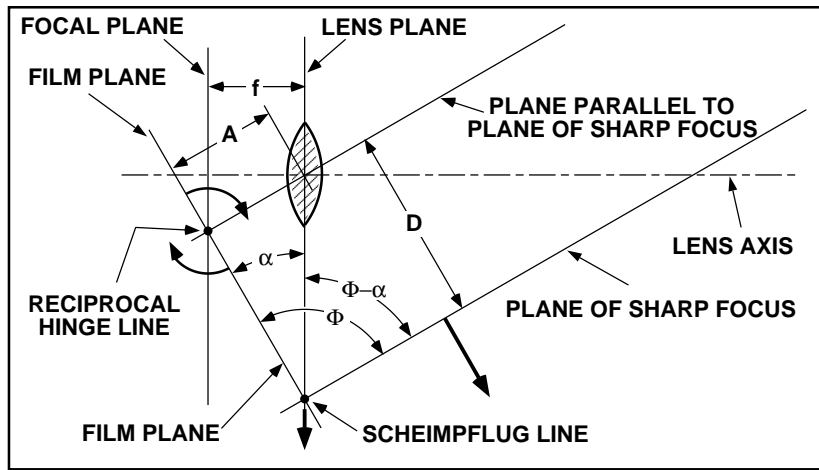


FIGURE 32: The reciprocal hinge rule states that if the film is rotated about the reciprocal hinge line in the direction shown, the Scheimpflug line moves downward along the lens plane. The Plane of Sharp Focus must then move farther from the lens, but without changing its angle relative to the lens plane. The angles α and Φ change, but $\Phi - \alpha$ does not.

made here is that the expected angle of view may be different from that expected, based upon the marked focal length of the lens. Tilting or swinging a lens changes its effective focal length.

The lens equation for *view cameras* can be written as:

$$\frac{1}{A} + \frac{1}{D} = \frac{\sin \alpha + \sin (\Phi - \alpha)}{f \sin \Phi} \quad (5)$$

where **A** is the lens-to-film distance, and **D** is the lens-to-plane of sharp focus distance. Both these distances are measured in a direction perpendicular to the respective planes of interest, as shown in Figure 31. The expression after the “=” sign is very nearly equal to $1/f$ for a surprising range of angles. If α and Φ are both less than 25° , for example, the error will be less than 10%. If α is less than 5° , Φ can be as large as 95° for a similar error.

It may also be observed that we can interchange **A** and **D**, or α and $\Phi - \alpha$, with no net change to Equation (5). This implies that there is a “reciprocal hinge line” and a “reciprocal hinge rule”. The reciprocal hinge line lies at the common intersection of the film plane, the (rear) focal plane, and a plane through the rear nodal point of the lens, parallel to the plane of sharp focus. The reciprocal hinge rule then states that if the film plane is rotated about the reciprocal hinge line, the plane of sharp focus moves closer to or

farther from the lens without changing its orientation. Figure 32 illustrates. I originally thought this might not be of much use. While reading a 1904 photography text by the British author Chapman Jones, however, I realized that it is essentially the reciprocal hinge rule that has allowed view camera users to use back tilt as a substitute for lens tilt. According to Chapman Jones, one should never attempt to adjust the camera using lens tilt. He claims that will just result in trouble. If one must set the lens axis out of perpendicular with the film, only back tilt should be considered—even though this may lead to unnatural perspective.

If one keeps the lens-to-film distance constant as one tilts a lens, the plane of sharp focus moves in a complicated way that is not easy to understand. The plane of sharp focus changes both its range from the camera and its angular orientation as the lens tilt is adjusted. Furthermore, the apparent movement of the plane of sharp focus depends upon the lens-to-film distance that is set. Thus the effect of tilting the lens is difficult to anticipate. It is very difficult to learn how to judge the right amount of lens tilt by adjusting the lens tilt directly. I refer in Chapter 10 to it being like driving a car on ice.

Adjusting the back tilt is a much ‘friendlier’—more predictable—operation. According to the reciprocal hinge rule, rotating the back about some fixed axis (on the film plane) merely regulates the distance of the plane of sharp focus from the camera without changing its angular orientation. The angular orientation is fixed by the relative positions of the lens and the axis about which the back is being tilted. The plane of sharp focus must remain parallel to the plane defined by the lens and the back tilt axis.

The reciprocal hinge rule makes it easier to understand some of the arguments over whether base tilts or axis tilts are preferable for the camera back. The ideal, I guess, is to be able to position the back tilt axis so as to determine the desired orientation of the plane of sharp focus.

The difficulty I see with using back tilts is how to maintain correct perspective. One solution I’ve heard proposed is to determine the required amount of tilt by tilting the back, but then transfer that amount of tilt to the lens (in the opposite direction) and straighten the back. This method is not rigorous. It often works well enough, but not always.

The lens equation for view cameras, Equation (5), implies that the effective focal length is always less than the nominal focal length of the lens. This may seem to be at variance with the statement made earlier to the effect that the effective focal length is often longer than the marked focal length. What really matters is where the main subject is relative to the lens axis. If the main subject initially lies near the lens axis, but the lens is tilted or swung to sharpen some other object, the focal length will seem to increase. If, on the other hand, the main subject is initially well off the lens axis, and one tilts the lens axis towards the main subject, the focal length will seem to decrease.

Tilt and Swing

So far, and for that matter almost throughout this book, it is assumed that we are looking at the camera in such a way that only lens tilt need be of concern. Now, real view cameras have tilt *and* swing movements for the lens. Having to accommodate both swing and tilt complicates the mathematics considerably, and so in this book I'll avoid that issue as much as possible. Two tables are included, however, to help out a bit. Tables IIa and IIb will eventually help us to deal with depth of field under circumstances where both tilt and swing are used. For small angles (less than 10 degrees) swing and tilt can be considered as independent of one another.

For the most part, in this book, I use the word “tilt” very generally to mean whatever angle the lens axis makes to a normal to the film plane. In standard view camera language, swing refers to the rotation of the lens carrier about a vertical axis. Tilt refers to the rotation of the lens about a horizontal axis. For most cameras, the tilt axis moves with the swinging of the lens carrier. Thus the swing and tilt motions interact to some extent.

If we use both tilt and swing, the total effective tilt—for the purposes of determining effective focal length and depth of field, for example—can be found from Table IIa. We simply read off the resultant value from the appropriate row and column. In this case, it does not matter whether the rows represent tilt and the columns represent swing, or *vice versa*. We just need to know the two numbers.

The swing and tilt do interact to affect the orientation of the plane of sharp focus. And here it does matter which is which. A useful way to describe the result is to examine the tilt of the hinge line in the PTF plane. Imagine, for example, that we have a camera with its film vertical. We tilt the lens forward and adjust the back focus so that the Plane of Sharp Focus lies horizontal. The hinge line is also horizontal. But, if we also swing the lens to the left, the plane of sharp focus rotates such that it rises on the left of the camera (if we are looking forward) and falls on the right. The hinge line must also rise on the left and sink on the right. The angle by which the hinge line rotates is given in Table IIb. I have used the symbol, θ , to represent this angle. I don't want to dwell on this matter, Tables IIa and IIb are included just to help out a bit in those frequent circumstances where the film plane is vertical.

Discussion

The view camera provides us with two focus controls: the lens tilt, and the back extension—that is, adjustment of the film-to-lens distance. Most users would consider the back extension to be the main focusing tool. As we have seen, however, the main thing that adjusting the back does is to change the *orientation* of the plane of sharp focus. Adjusting the back focus causes the

plane of sharp focus to rotate about the hinge line. Lens tilt, on the other hand, changes the *distance* (**J**) between the lens and the plane of sharp focus. Thus *lens tilt* is, in a sense, the true *distance*-regulating tool. The distance that lens tilt regulates is a bit strange in that it is measured in a direction parallel to the film. We usually think of focusing distance as measured perpendicular to the film.

I have not found it difficult to adapt to this different frame of reference. In fact, the advantages far outweigh the disadvantages. Instead of fiddling with seemingly endless cycles of adjust the tilt, focus, adjust the tilt again, refocus etc., I find I can now usually set the tilt—even before the camera is on the tripod—then set the back, and that's it, done, so far as focus is concerned! No more iterations.

It would be handy to do away with Tables III and IV by having a distance scale (instead of an angle scale) on the tilt adjustment mechanism. A true distance scale would require a different scale for each focal length. A **J/f** scale would be slightly less convenient, but one scale would serve for all lenses. An illustration of a tilt scale for a 180 mm lens may be found on page 56, at the end of Chapter 6.

These are the basic principles. The topics of perspective and distortion will be covered in the next chapter. And after that we'll use the principles described here to analyze the depth of field situation.

Chapter 5

PERSPECTIVE and DISTORTION

In Chapter 5 we will be addressing some aspects of perspective. Let me say at the outset that I am not an expert on perspective. Furthermore the terminology (language) I use here is not universal. The rules of perspective are, in my humble view, somewhat arbitrary; they are man-made standards rather than natural physical laws. The accepted conventions for perspective predate photography and even the camera obscura. Furthermore the rules have changed with time. My purpose in discussing perspective here is not primarily to establish what is correct perspective—although I will express opinions. Rather I wish to explain how the relative positions of lens and film influence geometrical distortion and hence apparent perspective.

For rectilinear lenses, tilting the camera lens has no inherent impact upon the apparent perspective of the image. Swinging or tilting a lens is a focusing operation. For the purpose of analyzing perspective, we can indeed best think of the lens simply as a pin-hole. A corollary to this is that when adjusting a view camera, we can consider the action of focusing and the action of controlling perspective quite independently. These two actions do not affect one another. These actions only become coupled if some other constraint—like the covering power of the lens—limits the degree of adjustment one should properly make.

That being said, the next logical question is: Well, what does control perspective? And, what is it anyway. Perspective in its most general terms means giving visual clues to the viewer of a two-dimensional image, so that he or she can interpret the image in three dimensions. These clues include such nuances as relative size, sharpness, and contrast. Contrasty objects are generally perceived to be closer than objects of low contrast, for example. Fuzzy objects are assumed to be closer than or more distant than the main, clearly delineated subject. The type of perspective I will address here, however, is restricted to geometrical shapes and sizes.

In the context of photography with rectilinear lenses, there are two effects of interest: image magnification and image distortion. One might even argue that there is only one—magnification—but the degree of magnification may be different in different directions. I find it easier to think in terms of relative magnification—how does image size change if I put the object here rather than there—and distortion—do the proportions (relative height and width) of the object change if it is moved from here to there. Both effects depend mostly upon one factor: how far off the principal axis is the image? Although the term “principal axis” was defined in Chapter 3, we haven’t needed it up until now. To recap, the principal axis is a line through the lens

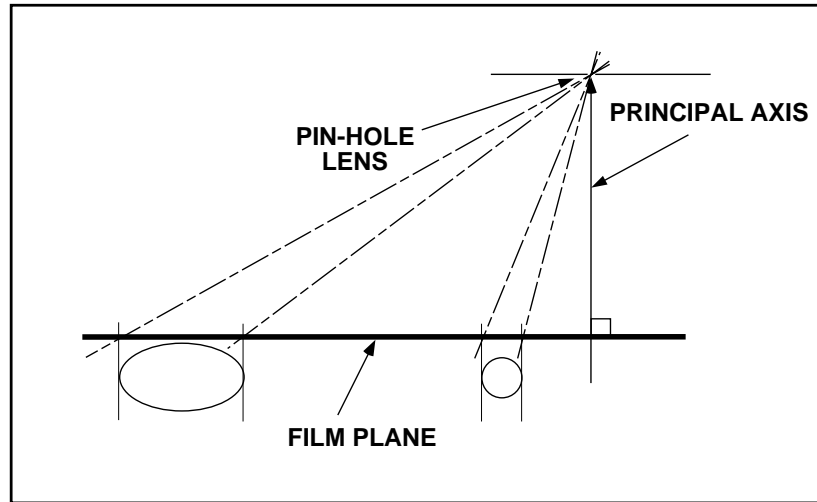


FIGURE 33: *The image of a spherical object (the moon, say) will be imaged near the principal axis as a circle. At a large angles off the principal axis (more than 30°) the same object at the same distance will be imaged as a somewhat larger ellipse. The image is magnified because the effective focal length of the lens is greater at this angle, and it is elongated because the imaging rays strike the film obliquely.*

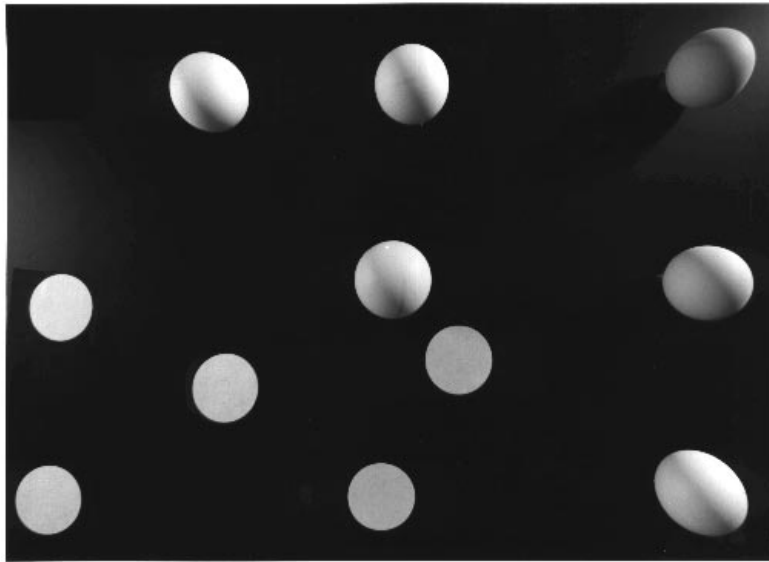


FIGURE 34: *Here's a photograph of six table-tennis balls and five round white dots taken with a 15 mm lens on a 35 mm camera. The balls in the corners show significant stretch while the ball in the very center is quite round. The dots, on the other hand are round no matter where they are—so long as the film plane is parallel to the object plane—as was the case here.*

and perpendicular to the film plane. Only near the principal axis are objects imaged in the proportions that reflect the true state of affairs.

When a small light ray bundle of circular cross-section strikes the film at an angle, the image on the film will not be circular, but rather elliptical: a circle that has been stretched in one direction. In one direction, perpendicular to a line from the image to the intersection of the principal axis and the lens plane, the image has the 'right' dimension. In the other direction, parallel to a line from image to the intersection of the principal axis and the lens plane, the image is too long. This is what I mean by distortion. How much too long depends upon how obliquely the ray bundle strikes the film. On the film plane near the principal axis, objects are imaged with negligible stretch. Far from the principal axis, the stretch can be significant. Figure 33 illustrates. What really matters here is the angle measured at the lens between the principal axis and the rays forming the particular image of interest. Within 25° to 30° of the principal axis, the stretch is almost unnoticeable. Beyond that it becomes increasingly noticeable; the stretch will reach a factor of two for rays 60° off the principal axis.

The implication of this phenomenon for perspective is that the flattening of a circle tends to make us think we are looking at the circle from an oblique angle. If we are looking at a sphere which gets flattened, however, we are confused: the image does not look real. In real life a sphere is always round, no matter how we look at it.

Figure 34 shows some table-tennis balls and some flat white dots mounted on a sheet of black cardboard. They are photographed from a distance of one foot with the widest-angle rectilinear lens I have: a Pentax 15 mm lens for 35 mm cameras. In this photograph the dots all look fine. The balls look fine near the center of the image, but rather strange near the corners.

Your eyes may notice a certain discrepancy between Figures 33 and 34. In Figure 33, the ellipse's smallest dimension is larger than the circle. In Figure 34, the 'width' of the ellipsoidal table-tennis balls is just about the same as diameter of the round table-tennis balls. Why the difference? The answer is that I drew Figure 33 to represent the images of two spherical objects each subtending the same angle at the lens. If the objects are of equal size, they must be at the same radial distance from the lens for this to be the case. Off the principal axis the image magnification is greater (as is the distortion) and so the image is larger. For Figure 34, the balls at the edges and in the corners are farther from the lens than is the ball at the center of the picture. One might expect therefore that their images would be smaller, but the magnification effect exactly cancels the size reduction due to subject distance.

If we concern ourselves only with the extent of an object measured in a direction parallel to the film plane, image magnification depends simply upon lens-to-image distance, **A**, divided by the lens-to-subject distance, **Z**. For images of three-dimensional objects, we need to consider the lens-to-image

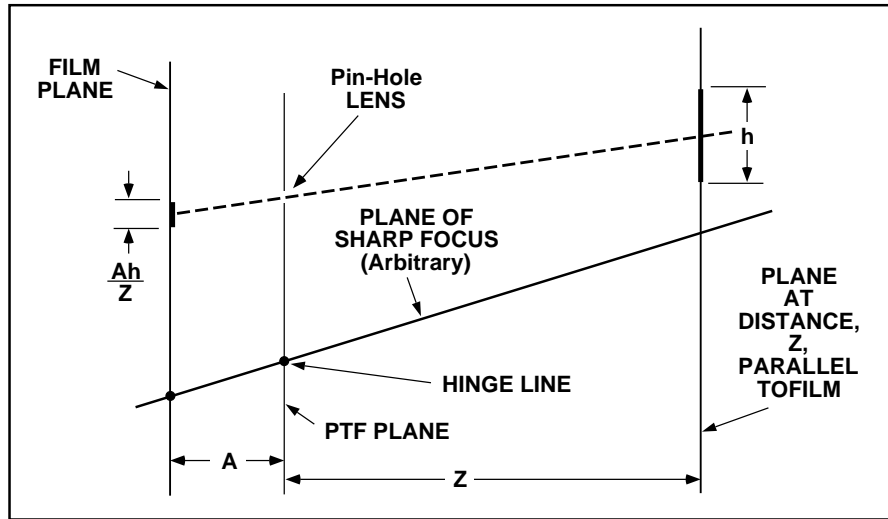


FIGURE 35: *Image magnification depends upon the lens-to-image distance divided by the lens-to-subject distance. There are subtle differences in how this works out for two-dimensional and three-dimensional subjects.*

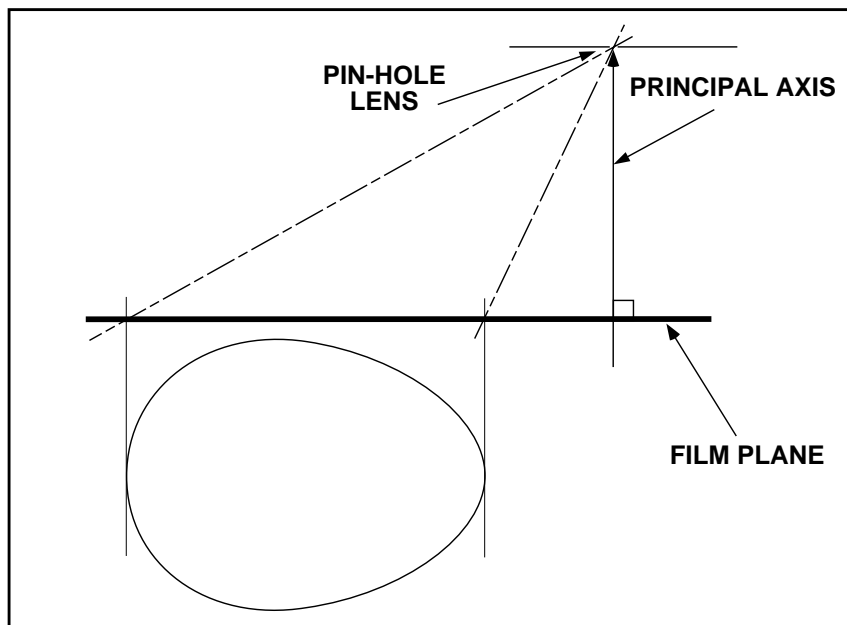


FIGURE 36: *If the image of a spherical object lies off the principal axis and also extends over a large range of off-principal axis angles, the image will be egg-shaped. The portion of the image farthest from the lens is magnified more than are other parts of the image nearer the lens.*

slant range divided by the lens-to-subject slant range. The shortest possible lens-to-image distance—and hence minimum magnification—will occur along the principal axis. 60° off the principal axis, image magnification will be twice what it is at the principal axis, assuming objects are uniformly distant from the lens. Figure 35 illustrates some of these considerations.

These elongation and magnification effects compound one another: the farther off the principal axis (in angular terms) an object lies, the greater is its magnification, and, the more stretch it undergoes. Even worse, for large objects subtending a significant angle at the lens, the magnification and stretch can be significantly greater at one side of the object than at the other. Figure 36 shows how a large image of a spherical object can become egg-shaped. What has happened here is that a) since the image is off the principal axis, the sphere is imaged as an ellipsoid and b) since the ellipsoid covers a wide range of magnifications, the end of it farthest from the principal axis is magnified significantly more than the end near the principal axis is.

Users of ordinary cameras equipped with wide angle lenses will be familiar with these “wide angle distortion” effects. A beach ball looks normal in the center of a picture, but more like a football near the corners of the image. And if the beach ball is close enough to the camera, so that its image is relatively large, the changing magnification from one end of the ‘football’ to the other will make it look more egg-shaped than football-shaped.

The ‘distortion control’ offered by view cameras is really nothing more than manipulation of the ‘wide-angle-distortion’ described above. What makes the view-camera different from the normal SLR, say, is that in the case of the view camera we see only a portion of the total picture. If the view camera photographer selects that portion near the principal axis, we see a relatively normal image. But he can equally well select the very outside of the lens coverage circle, where stretch is at a maximum, and where magnification is varying most rapidly. And so he can turn beach balls in the very center of the final image into eggs—or *vice versa*.

Although lenses made for view cameras usually have lots of covering power, even lenses of modest covering power can be made to yield excessive distortion. All the view camera photographer needs to do is to swing the camera back. Figure 37 shows how. In this case there is no image at all where the principal axis meets the film plane. But the film is illuminated at a steep angle, and hence the distortion effects are significant. In this case the photographer might have a focusing problem, but then again, for the right subject, this geometry might be exactly what he needs. I note in passing that there is an exposure factor to consider also when the imaging rays fall obliquely on the film. The image intensity is reduced because the same bundle of light is spread over a larger area of film. If the light rays fall at a 45° angle to the film, one must open the lens by one stop (or double the exposure time) to compensate. At 60° off the principal axis, the compensation required is two stops.

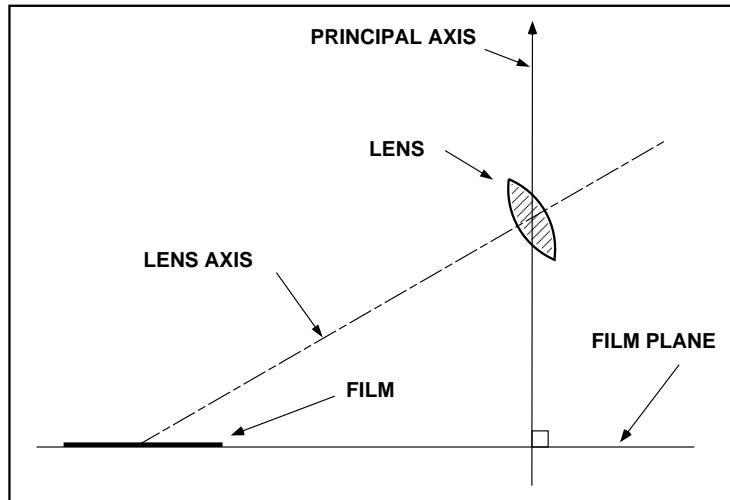


FIGURE 37: *If the image of a spherical object lies off the principal axis and also extends over a large range of off-principal axis angles, the image will be egg-shaped. The portion of the image farthest from the lens is magnified significantly more than are other parts of the image nearer the lens.*

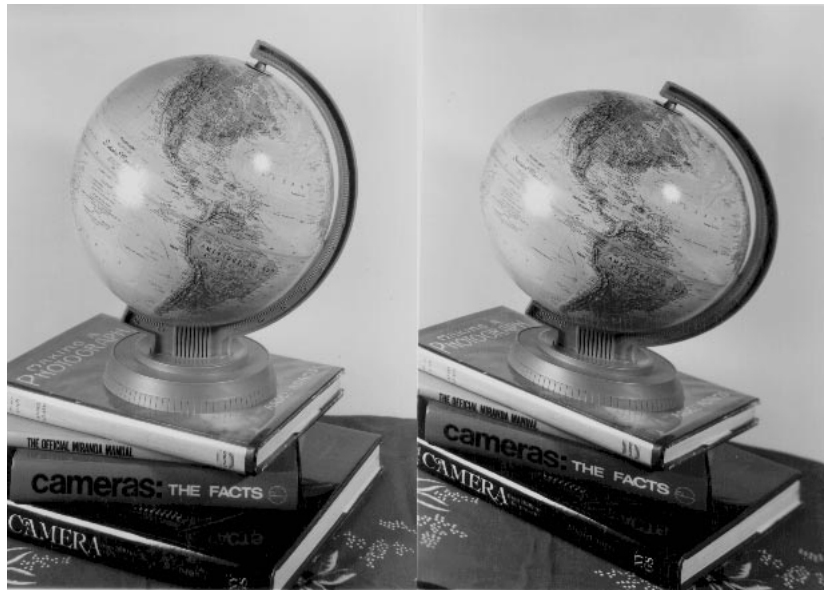


FIGURE 38: 38 a) show a relatively normal photograph of a globe. 38 b) shows the same object from essentially the same camera position, but with the camera back swung by 40° . The world no longer appears spherical, and the books seem to be lying on a slope.

Figure 38 shows exactly the situation just described. Figure 38a shows a quite normal photo of a globe. For this photograph I used only back rise and front fall to obtain a downward viewing angle. The globe is very slightly taller than it is wide as a result, but one can hardly notice it. Figure 38b shows what happens when I swing the back by 40° . It was also necessary in this case to swing the front by 20° to maintain reasonable focus. I would have used greater back swing to exaggerate the effect even more, but the camera bellows would not allow that without cut-off of the image. Figure 38b was also taken from slightly farther away than Figure 37a, just to let the globe fit comfortably in the frame.

When reproducing images of flat subjects such as drawings or paintings, it is important that the film plane and the object planes are parallel. This will ensure that any distortion of the image by the camera will exactly compensate the natural perspective distortion that exists when we look at a drawing at an angle. If we were to look objectively at the object from the position of the lens, we would see that the extreme corners looked small and foreshortened—that is, squashed in one direction. But the intentional distortion introduced by a rectilinear lens exactly compensates and ensures that the final image looks ‘right’. This is why the flat white dots in Fig 34 still look circular.

Perhaps the most common examples of a distorted but ‘correct’ images are pictures of buildings. By convention, tall buildings are represented in art and photography with vertical lines that do not converge, and in some cases even with horizontal lines that do not converge. Preventing converging vertical lines is simple: keep the principal axis horizontal. This means keeping the film plane vertical. Keeping horizontal lines from converging is also simple: keep the principal axis perpendicular to the horizontal lines in the image. If we are photographing a building in such a way that we can see only one face of the building, we usually want to keep both horizontal and vertical lines from converging. This is done by holding the principal axis perpendicular to the visible face of the building. In other words, we keep the film plane parallel to the face of the building. We can position the lens anywhere, but keep the film parallel to the building.

If, in another example, one can see two faces of a building (the front and one side, for example), the convention states that we maintain only the vertical lines parallel; we let the horizontals converge. We can still play with the orientation of the principal axis in the horizontal plane. The most natural image usually results when the principal axis is pointing at about the center of the building. There is some freedom, however, to exaggerate the apparent perspective. In general, the building will tend to look as though it is being viewed in a direction parallel to the principal axis—even when that is not the case.

Figure 39 illustrates two images of a building from the same camera position. Figure 39 a) shows a building taken using front rise only. (Well, actually, I also tilted the lens down a bit to sharpen the foreground.) Vertical



FIGURE 39: a) shows a 'correct' image of a building. Front rise only was used for this photo. In b) the back was swung by almost 38° to give a rather odd and 'incorrect' image. This second photo looks in some ways as though it was taken from a camera position to the photographer's right. But other clues indicate this is not the case: we can see the left side of the building, for example, and we know that most buildings have 90° corners. Swinging the back also stretches the image horizontally.

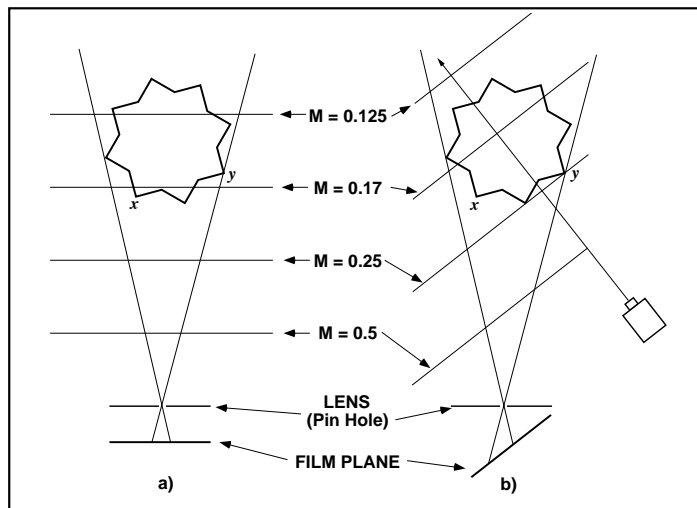


FIGURE 40: Planes of constant magnification lie parallel to the film plane. In a) above, the film plane lies at right angles to the main line of sight of the camera, resulting in normal perspective. In b), the camera back has been swung by about 38° , yielding magnifications characteristic of the 'box camera' at right. Note how the magnification at point x is greater than that at y in the case of a), but the reverse is true in b).

lines are vertical and horizontal lines converge: for the left face they converge to the left and for the 'front' face they converge to the right. For Figure 39 b) I moved the back by about 38° (counterclockwise if one is looking down on the camera). The lens also needed to be swung to re-establish acceptable focus. This somewhat extreme back swing causes the horizontal lines for the 'front' of the building to converge to the left instead of to the right. The result tends to make the photograph look as though it was taken from a position further to the photographer's right. This photograph is not 'correct'; the viewer is confused by the mixed visual clues.

The significance of planes in front of the camera but parallel to the film plane is that small spherical objects (or subject elements) on any one of these plane will be reproduced in the image at a consistent magnification. That is, an object on any one such plane will be the same size in the image, no matter where on the plane it lies. We can thus 'map' image magnification as a system of parallel lines. If we swing the back, we change the orientation of these constant-magnification planes in the object space. The new 'magnification map' is skewed. But it is precisely consistent with a different camera position. Thus swinging the camera back results in an image which has the magnification of one (phantom) camera position, but an arrangement of image elements characteristic of another (the true) camera position. See Figure 40.

I have seen examples in books where it is stated that the proper view camera solution to photographing a wall obliquely will involve both lens swing—to maintain focus—and back swing—to "restore" the proper perspective. I do not believe this is correct. I suggest that what has happened is that when the photographer adjusted the lens for proper focus, he discovered that the horizontal lines no longer converged to the degree he expected. The true cause was an effective change in focal length, but the photographer interpreted the result as a change in apparent perspective. To achieve the expected convergence of the horizontal lines in the image, he adjusted the back. This is not a serious error; for the most part, it is all a matter of art and taste.

So, the lesson for this chapter is that, for the purposes of perspective, lenses act like a simple pin hole. All that matters is where the image is in relation to the principal axis—a line perpendicular to the film plane and passing through the pin hole. Near the principal axis, images are reproduced more or less naturally. For images formed at large angles from the principal axis, the image is stretched in one direction and magnified. The view camera is able to reproduce this 'wide angle distortion' even with lenses which are not wide-angle. As a vague guide, images often tend to look as though the camera's line-of-sight were along the principal axis of the camera—even when such is not actually the case. This has not been a complete guide to perspective; the major points are that lens orientation (swing and/or tilt) does not affect perspective, rather, it is the angle of incidence of the image rays on the film that determines the effect.



The Ottawa River, looking west

Here, I used about 9° of forward lens tilt in order to have the plane of sharp focus pass just under the feet of the tripod. The plane of sharp focus falls a bit as it proceeds away from the camera, passing through the tree just right of center.

Chapter 6

DEPTH OF FIELD

There are at least two ways to think about depth of field. In the traditional treatment of the depth of field, one uses the following logic. First establish an image resolution criterion—expressed by the maximum permissible size of the circle of confusion. Then determine the depth of focus needed to achieve that circle of confusion for the lens aperture being used. Finally, calculate where objects may lie in order that their images are at the extreme limits of the permissible depth of focus.

Another possible philosophy is that described in *The INs and OUTs of FOCUS*. In this “object field method”, one first asks what resolution is required at the object. Then one calculates what is necessary to achieve it in terms of the physical lens aperture diameter and the distance to the plane of sharp focus. The object field method has the advantages that we can adjust the required resolution to suit the requirements of the individual picture, and that precisely the same calculations work for all formats and all focal lengths.

Both of these methods can be applied to view cameras. And they are, of course, completely consistent with one another. First, we’ll look at the traditional method. This method is probably more familiar to you. This scheme is, however, the more complex of the two, especially where view cameras are concerned. As we’ll later see in the Chapter 7, the simplest route to the image-based solution is via the object-based method—but we’ll look at the traditional methods first.

Image-Based Depth of Field

Following the steps outlined for the traditional method above, we set the maximum diameter of the circle of confusion as **a**. The permissible focus error is then (approximately) $\mathbf{g} = \mathbf{Na}$, either side of the film plane, where **N** is the f-number. Imagining that the film plane were moved to one extreme limit of the depth of focus and then the other, the plane of sharp focus moves through a wedge-shaped region of space in front of the camera. This wedge describes the region within which objects will be imaged at the film with a circle of confusion smaller than diameter **a**.

We need, then, to decide what diameter to use for the maximum diameter of the circle of confusion, and then how to describe that wedge. First we’ll consider the size of the circle of confusion. One of the often-used

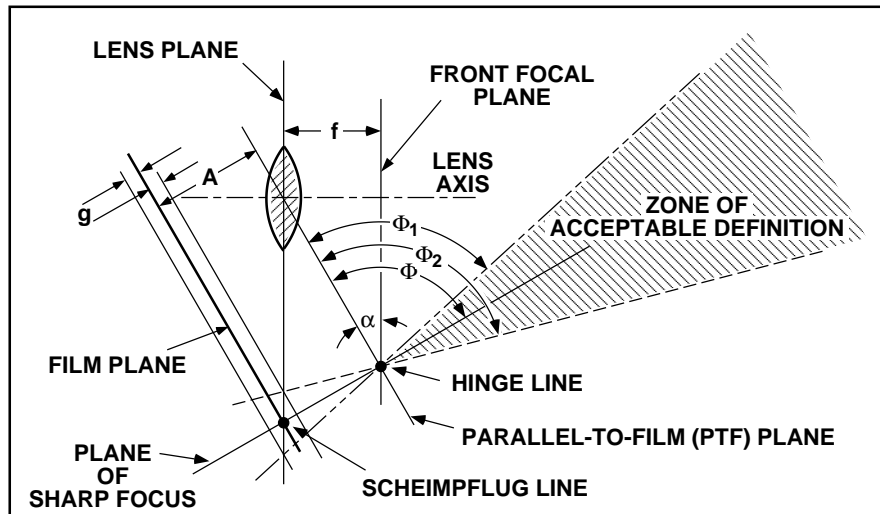


FIGURE 41: For an allowable depth of focus $\pm g$, the depth of field extends from Φ_1 to Φ_2 : the shaded area above.

numbers is one fifteen-hundredth of the focal length of the lens. This corresponds to the 1/30 mm number often used for 35 mm cameras, for example. It is indeed convenient to use some fraction of the lens focal length, because it will turn out that we can make one set of tables serve for all lenses that way. I offer the caution, however, that it may actually make more sense to use some fraction of the format diagonal rather than focal length. It will be easy to change criteria anyway, because the determining factor is the depth of focus which is simply the product of the f-number and the diameter of the circle of confusion. Thus one table can serve for many combinations of **a** and **N**, so long as the product of **a** and **N** remains unchanged.

I propose two ways to describe the depth-of-field wedge. The straight forward way is to state the angles between the film plane and the depth of field limits. The angle for the 'near' limit of depth of field—on the lens side of the plane of sharp focus—will be called Φ_1 . The angle to the limit of depth of field on the far side of the plane of sharp focus will be called Φ_2 . See Figure 41.

Angles are not always easy to estimate in the photographic environment, and so I propose a second alternative. Suppose we wish to determine the depth of field, about the plane of sharp focus, some specified distance in front of the camera. We can express the depth of field measured in a direction perpendicular to the plane of sharp focus as a fraction of the lens-to-plane of sharp focus distance. To keep things consistent, we'll measure the lens-to-plane of sharp focus distance in a direction perpendicular to the film plane. The way of measuring things just described will not always seem

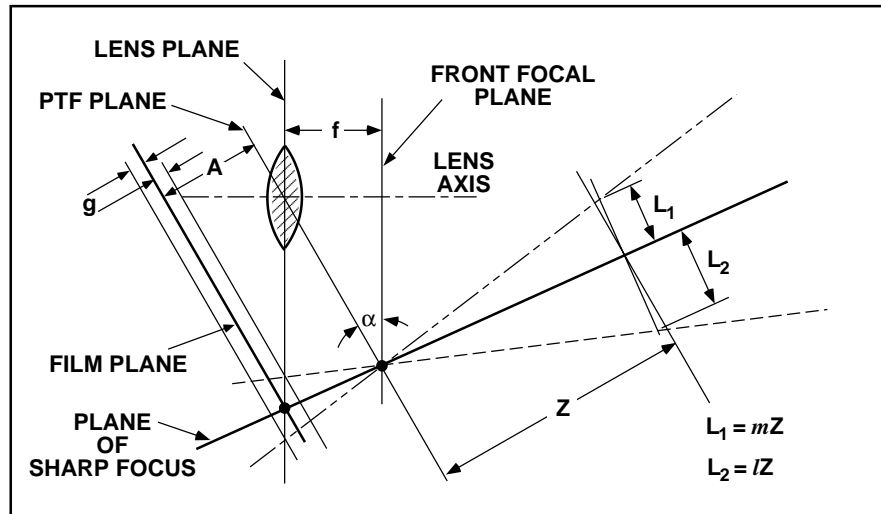


FIGURE 42: For an allowable depth of focus $\pm g$, the depth of field can also be described in a direction perpendicular to the Plane of Sharp Focus, shown here by the symbol L , and expressed as a fraction of the distance, Z .

natural, but we have to be consistent. This scheme of things is shown graphically in Figure 42.

Expressing depth of field as a fraction of the lens-to-plane of sharp focus distance has its limitations. It is possible for the depth of field to become too large to be described accurately this way. If the angle between Φ_1 or Φ_2 and Φ becomes equal to or greater than 90° , the depth of field, expressed as a fraction of the lens-to-plane of sharp focus distance, becomes infinite. In practice, this usually does not present the photographer with a problem. When the depth of field is that great, it is usually more than sufficient for the purpose. And if that is not the case, we can probably estimate angles well enough that the angular description of depth of field can be used instead.

The depth of field tables at the back of this book, Tables VII to XVII, are organized in pairs for each f-stop from $f/2.8$ to $f/90$. The left-hand, or upper-most table shows the limits of depth of field expressed by angle. The right-hand page, or lower table, shows the depth of field as a fraction of the distance Z . The tables are calculated for a maximum circle of confusion of one-fifteen-hundredth ($1/1500$) of the lens focal length. But each table is actually valid for a number of combinations of f-number and circle of confusion size. A few of the applicable combinations are listed on each table. Note that each table applies for lenses of all focal lengths. Since the distance J is given as J/f , however, the appropriate value of J/f must be re-calculated if the lens focal length is changed.

When changing lenses, care will be needed in choosing the right table to use. Let's suppose we are using a 4×5 in. camera and presume the 150 mm lens is the 'normal' focal length. One-fifteen-hundredth of 150 mm is 0.1 millimeters. We thus might choose $a = 0.1$ mm. For the 150 mm lens we can then use the depth of field table for the main f-stop as marked on the table. If we switch to a 90 mm lens for that same camera, we will probably still wish to use $a = 0.1$ mm. But 0.1 mm is no longer one-fifteen-hundredth of the focal length. With the 90 mm lens, the ratio a/f is 0.1/90 or one-nine-hundredth of the focal length. The closest a/f value shown on the tables is 1/1000. If we look at the combinations of f-number and a/f values shown on the tables, we will see that the f-stop opposite $a/f = 1/1000$ is one stop larger than the f-stop for $a/f = 1/1500$. What this means in practice is that the same table that applies to the 150 mm lens at f/22 *also* applies to the 90 mm lens, *but at* f/16. The tables have a blank space in the bottom left corner. The purpose of that space is to provide a place for your notes on what combination of f-stop and lens focal length is appropriate in your case. Similarly, if you were using a 210 mm lens on that 4×5 camera, the f/22 table would apply, but at f/32 for the 210 mm lens. Thus in this case you might write in that space for the "f/22" table:

"90 mm: f/16;
150 mm: f/22;
210 mm: f/32."

Although the depth of field fractions are given in the many tables, it can be instructive to show you the algebraic expressions for them. There are many ways to manipulate the formulae, but perhaps the most useful are the following:

$$m = \frac{L_1}{Z} = \frac{gD/A^2}{1 + \frac{gD \cos(\Phi - \alpha)}{fA}} \quad (6a)$$

or

$$m = \frac{L_1}{Z} = \frac{[gJ \sin(\Phi - \alpha)]/fA}{1 + \frac{gJ \sin(\Phi - \alpha) \cos(\Phi - \alpha)}{f^2}} \quad (6b)$$

and

$$l = \frac{L_1}{Z} = \frac{gD/A^2}{1 - \frac{gD \cos(\Phi - \alpha)}{fA}} \quad (7a)$$

or

$$l = \frac{L_1}{Z} = \frac{[gJ \sin(\Phi - \alpha)]/fA}{1 - \frac{gJ \sin(\Phi - \alpha) \cos(\Phi - \alpha)}{f^2}}. \quad (7b)$$

These expressions tell us several things. First, there are many circumstances under which the depth of field is proportional to **J** or **D**. Increasing **J** or **D** increases depth of field, even when the distance **Z** remains unchanged. Thus using less lens tilt will usually increase depth of field. Another curious item is that when $\cos(\Phi - \alpha)$ is equal to zero, depth of field is precisely symmetrical about the plane of sharp focus. This situation will normally occur when Φ is a little more than 90° . The depth of field is also symmetrical whenever **J** and **D** are quite small.

The expressions given in Equations (6) and (7) lead exactly to the standard depth-of-field relations for ‘normal’ cameras when appropriate substitutions are made for zero lens tilt.

Object-Based Depth of Field

The object field method for dealing with depth of field does not require tables *per se*. There is a simple relationship between lens diameter, distance to the subject, distance to the plane of sharp focus and resolution spot size. That relation is:

$$K = R \frac{S}{d} \quad (8a)$$

or

$$L = D \frac{S}{d} \quad (8b)$$

where **S** is the resolution spot size, **D** is the distance from the lens to the plane of sharp focus, **R** is the distance along a ray from the lens to the plane of sharp focus and **d** is the physical diameter of the lens (at its working aperture). (In *The INs and OUTs of FOCUS*, **S** was called the “disk-of-confusion”.) The depth of field is either **K** or **L** as described following. If we work with distances measured along a ray from the lens, passing through some point on the plane of sharp focus, we will call the depth of field **K**. **K** is the depth of field on either side of the plane of sharp focus, measured along the ray, as shown in Figure 43a. Another alternative is to measure the lens-to-plane of sharp focus distance in a direction perpendicular to the plane of sharp focus, as shown in Figure 43b. In this case we use the distance **D** as the lens-to-plane of sharp focus distance. The depth of field is then expressed as a distance perpendicular to the plane of sharp focus. For depth of field measured

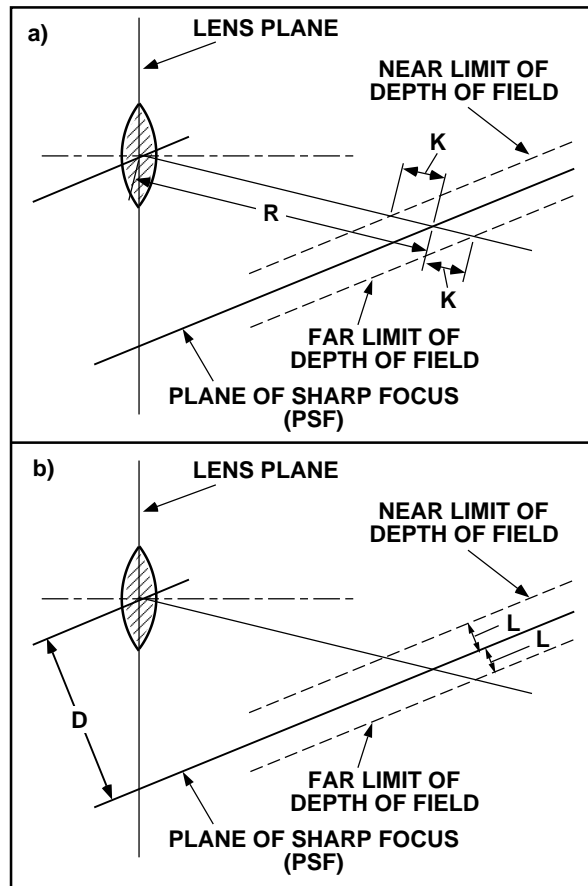


FIGURE 43: *For the Object Field Method of describing Depth of Field, the depth can be expressed either as K in a direction along a ray, or as L in a direction perpendicular to the Plane of Sharp Focus. In either case, the Depth of Field is always symmetrical for the object field method.*

perpendicular to the plane of sharp focus, we use the symbol L . In this object field description of depth of field, there is no need to use subscripts to indicate which side of the plane of sharp focus is intended: the depth of field is *always* symmetrical about that plane for the object field method.

The lens-to-plane of sharp focus distance, D , can sometimes be measured or estimated conveniently, but sometimes not. To help with those cases where D cannot be measured easily, Table XVIII is included to express

the distance, D/f , in terms of J/f and Φ . The mathematical formula for the relationship is:

$$\frac{D}{f} = \frac{J}{f} \sin \Phi. \quad (9)$$

Discussion

Depth of field for view cameras sometimes appears to behave a little differently from that experienced with normal cameras. In particular, it might help to remember that focusing farther away tends to increase depth of field. We, of course, know that with normal cameras depth of field increases as we focus farther away. That same principle applies for view cameras, but it is not always so obvious just what focusing farther away means. We have two ways of focusing the view camera, back extension—changing the lens-to-film distance—and lens tilt. Tilting the lens always brings the plane of sharp focus closer to our lens. And thus tilting the lens usually means decreasing depth of field. If there are two or more ways to solve our focus problem, the solution using the least amount of lens tilt will usually give us the greatest useable depth of field. On the other hand, if limited depth of field is the goal, try for a camera angle that requires lots of lens tilt.

In Chapter 7, we'll look at a very simple way to estimate depth of field. In order to make the simplification, it will be necessary to measure depth of field in yet another direction: parallel to the film plane.

Depth of field for view cameras does not always behave as one might have thought. In Chapters 8 and 9, specific examples will be described. We'll see in Chapter 8 that, under some circumstances, focusing farther away can actually make some things close to the camera sharper.



A Focusing Scale for Tilt

*It is not necessary to use tables or a calculator to determine the required lens tilt. Here's an example of a tilt scale fitted to a Toyo view camera. The scale shows directly the **J** distance in feet for the degree of tilt implemented (assuming the camera back is not tilted). A separate scale is needed for each focal length. Here the scales are held in place by a magnet, and can easily be changed with the lens. The scale shown is that for a 180 mm lens. For the amount of tilt applied here, the distance, **J**, is just under 2 feet.*

Chapter 7

A SIMPLER METHOD

In the previous chapter, diagrams were drawn to show the boundaries of the zone of acceptable sharpness in relation to the scene being photographed. These drawings were made by using the depth of field tables of Chapter 11. But there is another way to draw them. This second way is just as accurate, but requires that we establish yet another direction in which to measure depth of field. A familiar concept comes to the surface: the hyperfocal distance. The definition of hyperfocal distance used here is precisely the same as for ordinary photography, but the way we make use of it is quite different.

I mentioned in the previous chapter that the simplest way to derive image-based depth of field result for view cameras is actually via the object field method. The method is also exact. It works like this.

With reference to Figure 44, the derivation is as follows. The diameter of the disk-of-confusion, or spot size, is zero on the plane of sharp focus (PSF). Along any straight line intersecting the PSF, the spot size, S , changes.

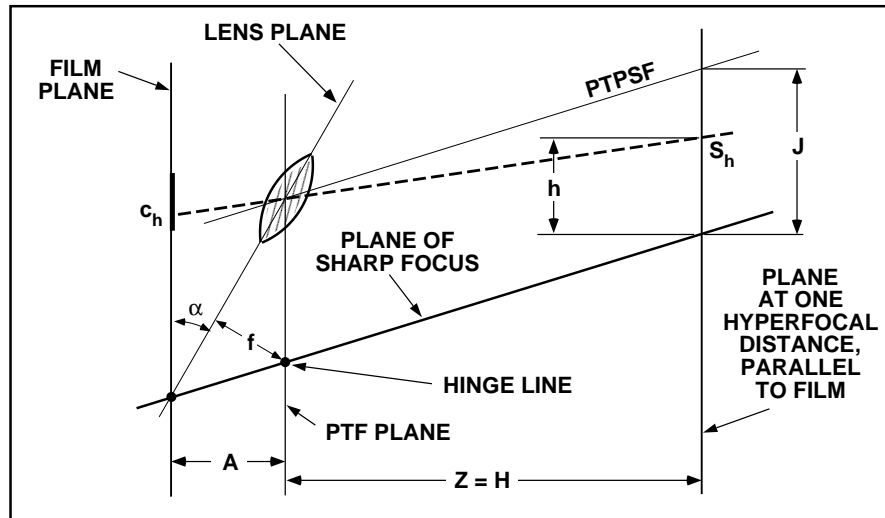


FIGURE 44: Here's the general scheme of things needed to determine the exact image-based depth of field from a knowledge of the object space depth of field. "PTPSF" stands for the plane which is Parallel To the Plane of Sharp Focus. The spot size diameter, S_h , is determined in relation to its distance from the plane of sharp focus, h . The corresponding diameter of the circle of confusion is determined by the image magnification.

Along any line parallel to the film plane and in the object field, \mathbf{S} will simply be:

$$\mathbf{S}_h = \mathbf{d} \frac{\mathbf{h}}{\mathbf{J}}$$

where \mathbf{d} is the lens aperture diameter and \mathbf{h} is the distance from the PSF measured along that line parallel to the film. On the film, the image of that spot will be simply the magnification times \mathbf{S}_h . That is:

$$\mathbf{c}_h = \frac{\mathbf{A}}{\mathbf{Z}} \mathbf{d} \frac{\mathbf{h}}{\mathbf{J}}.$$

In order for \mathbf{c}_h to be less than \mathbf{a} , the maximum permitted diameter of the circle of confusion, we require:

$$\frac{\mathbf{A}}{\mathbf{Z}} \mathbf{d} \frac{\mathbf{h}}{\mathbf{J}} < \mathbf{a}$$

or

$$\mathbf{h} < \frac{\mathbf{a}}{\mathbf{d}} \mathbf{J} \frac{\mathbf{Z}}{\mathbf{A}}.$$

Since $\mathbf{d} = \mathbf{f}/\mathbf{N}$, and $\mathbf{H} = \mathbf{f}^2/\mathbf{N}\mathbf{a}$, we have:

$$\mathbf{h} < \frac{\mathbf{f}}{\mathbf{A}} \mathbf{J} \frac{\mathbf{Z}}{\mathbf{H}}.$$

For the limit of depth of field, we then replace the “less-than” sign ($<$) by “equals”. That’s all there is to it. Of course one has to believe what’s in *The INs and OUTs of FOCUS* first. There’s no trigonometry required either in this derivation, or in the result! There’s still just a bit of trigonometry needed to calculate the distance \mathbf{J} from the lens tilt, α .

What this says is that depth of field can be described as shown in Figure 44. If we measure depth of field in a direction parallel to the film plane, the depth of field, either side of the plane of sharp focus, is just \mathbf{Z} times $\mathbf{f}\mathbf{J}/\mathbf{A}\mathbf{H}$. And since \mathbf{f}/\mathbf{A} is just about equal to one except in close-up situations, this means we can usually state that the depth of field measured parallel to the film plane is \mathbf{Z} time \mathbf{J}/\mathbf{H} . For \mathbf{f}/\mathbf{A} approximately equal to one:

$$\mathbf{L}_{\text{pf}} \approx \frac{\mathbf{Z}\mathbf{J}}{\mathbf{H}}. \quad (10)$$

\mathbf{L}_{pf} stands for the depth of field measured in a direction *parallel* to the *film* plane (hence the subscript **pf**). Depth of field so measured, and to the degree of approximation used, is *always* symmetrical about the plane of sharp focus.

(A minor detail that has been raised is: “Is \mathbf{H} equal to $\mathbf{f}^2/\mathbf{N}\mathbf{a}$, or is \mathbf{H} equal to $\mathbf{f} + \mathbf{f}^2/\mathbf{N}\mathbf{a}$?” The answer is “yes”. I have found four slightly different definitions for hyperfocal distance. Two of them give the answer with the extra \mathbf{f} in it. One gives only the \mathbf{f} -squared term. The fourth is more complex. The definition I used in *The INs and OUTs of FOCUS*, yields the simplest

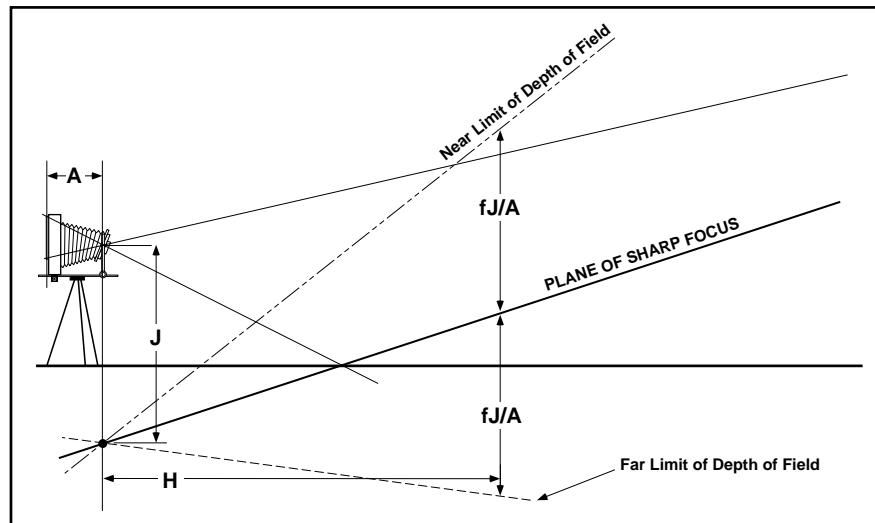


FIGURE 45: The exact calculations for depth of field require that the depth of field at one hyperfocal distance be fJ/A , rather than just J . The matter is of little consequence except in close-up photography.

expression ($H = f^2/Na$) when I do it 'right'. The four definitions are: The inner limit of depth of field, measured from the lens, when the lens is focused at infinity (as in my book); same again measured from the film; The distance (measured from the lens) which, when focused upon, gives infinity as the far limit of depth of field; and, this last again, but measured from the film. The differences are subtle and inconsequential for most purposes.)

This result requires that we use the *marked* f-number for the aperture rather than the 'true' f-number, no matter how large A is. That's just *less* calculation to do! (The depth of field tables at the end of this book assume one will always use the 'true' f-number. (At 1:1 image magnification, for example, the true f-number is twice that marked on the lens.) I have not been consistent!

We make use of just the location of the camera lens, the distance, J , the parallel-to-film lens plane (PTF plane), and a couple of other planes parallel to the PTF plane, but one hyperfocal distance from it. That's all we need to know in order to make this work! Information about the lens tilt is contained in the distance, J , along with the lens focal length. The lens focal length, the lens aperture and the diameter of the circle of confusion are contained in the hyperfocal distance.

Based on the forgoing, there's a graphical scheme that can be used to help convert depth of field results to the angular description of the previous chapter (and the tables in Chapter 11), should that be needed.

We begin with a clean sheet of paper. Vertically down the center, we draw a line representing the PTF plane. About in the middle of the page, place

a dot along it. This dot represents the position of our camera lens. Assuming we will be using forward lens tilt, we will place another dot along the PTF plane to represent the hinge line. The distance between the two dots represents the distance J . At this stage we need to decide upon the scale of our drawing. (We *can* have two scales: one for vertical distances and another for horizontal distances, but angles do not appear correctly if we do that.) All distances will be measured in hyperfocal distances, including vertical distances such as the lens-to-hinge line distance. This way, we can use the same diagram for all our photographic situations. It does mean a little work with a calculator to determine what the real distances are, however. Next, we draw two more vertical lines (parallel to the PTF plane) to represent planes one hyperfocal distance either side of the PTF plane. Figure 46 shows the diagram so far. We can use this diagram as a template for almost any picture-taking situation. The angle scale, centered upon the lens position, is shown around the outside of the diagram. An example will be shown in the next chapter.

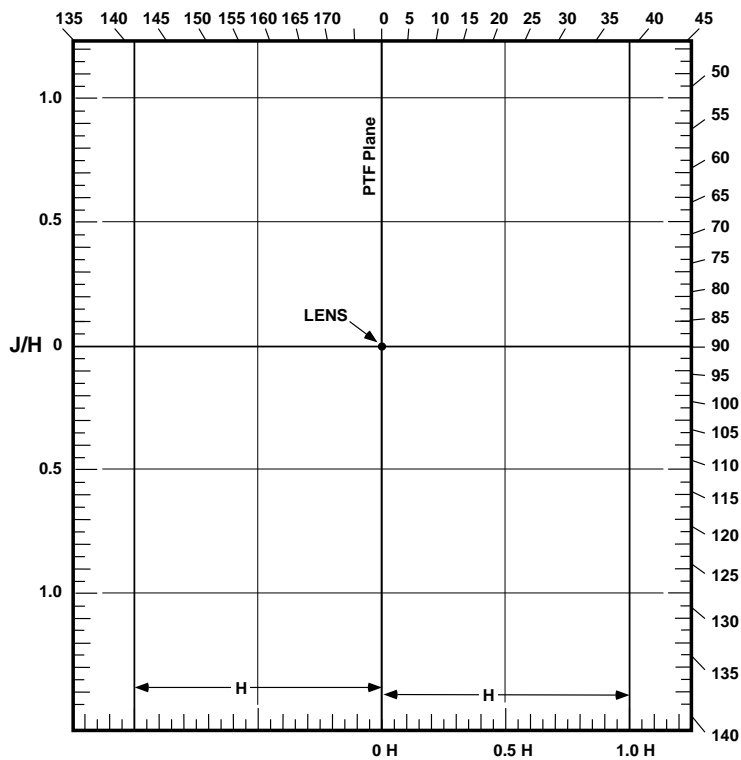


FIGURE 46: Here's our blank depth of field chart showing the lens, the PTF plane, and two additional planes one hyperfocal distance either side of the PTF plane. It will be necessary to plot the distance, J , in units of one hyperfocal distance.

Chapter 8

AN EXAMPLE

The theory in the previous chapters may have been a bit abstract for you. In this chapter, I'll try to show how these things were applied in the taking of a real picture—the picture shown overleaf, on page 62. I'll start by describing the geography of the location, then indicate how the camera was adjusted, and how the depth-of-field was verified. I'll use both 'kinds' of depth of field for this analysis: the image-based method and the object field method. The image field method is a good one for determining in a general way what will happen, but when precision is necessary, the object field method is often more informative. I'll close by indicating some focus effects that may not be immediately obvious.

Figure 48 is a photograph of the Francon "Cement Plant" near where I once lived. Figure 47 below is a sketch of a sideways view of the camera, the land and the cement plant tower. The camera is about level with the base of the tower, but between the camera and the tower is a marshy grassy area about 10 feet below the camera lens. The tower is about 300 feet away and about 70 feet high. In the foreground, at the near edge of the marsh, are some daisies. My goal was to photograph the scene with everything sharp from the daisies to the antenna on top of the tower. Some trees in the near ground could not be accommodated, but that was judged not to detract from the image.

The camera was a 5×7 in. B&J view camera with a 9.5 in. Goerz American f/6.8 Gold Ring Dagor. 9.5 inches is about 241 mm. My image resolution criterion will be 1/1500 of the focal length. Since the tables are set up primarily for this criterion, I am able to use the tables as printed.

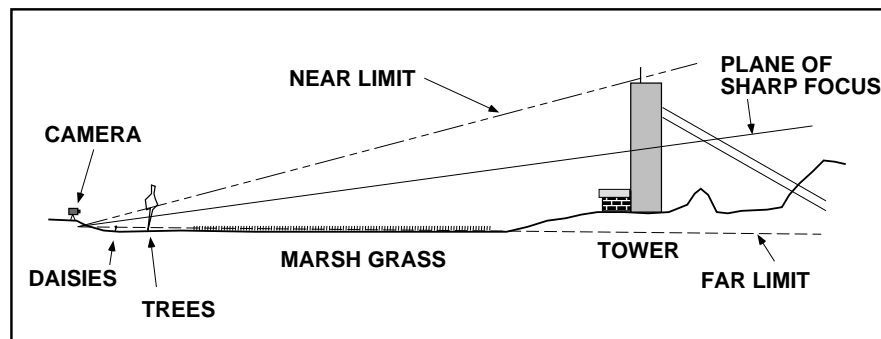


FIGURE 47: *Here's a cross-section through the scene to be photographed. The lines show the desired limits of depth of field and the probable position of the Plane of Sharp Focus.*

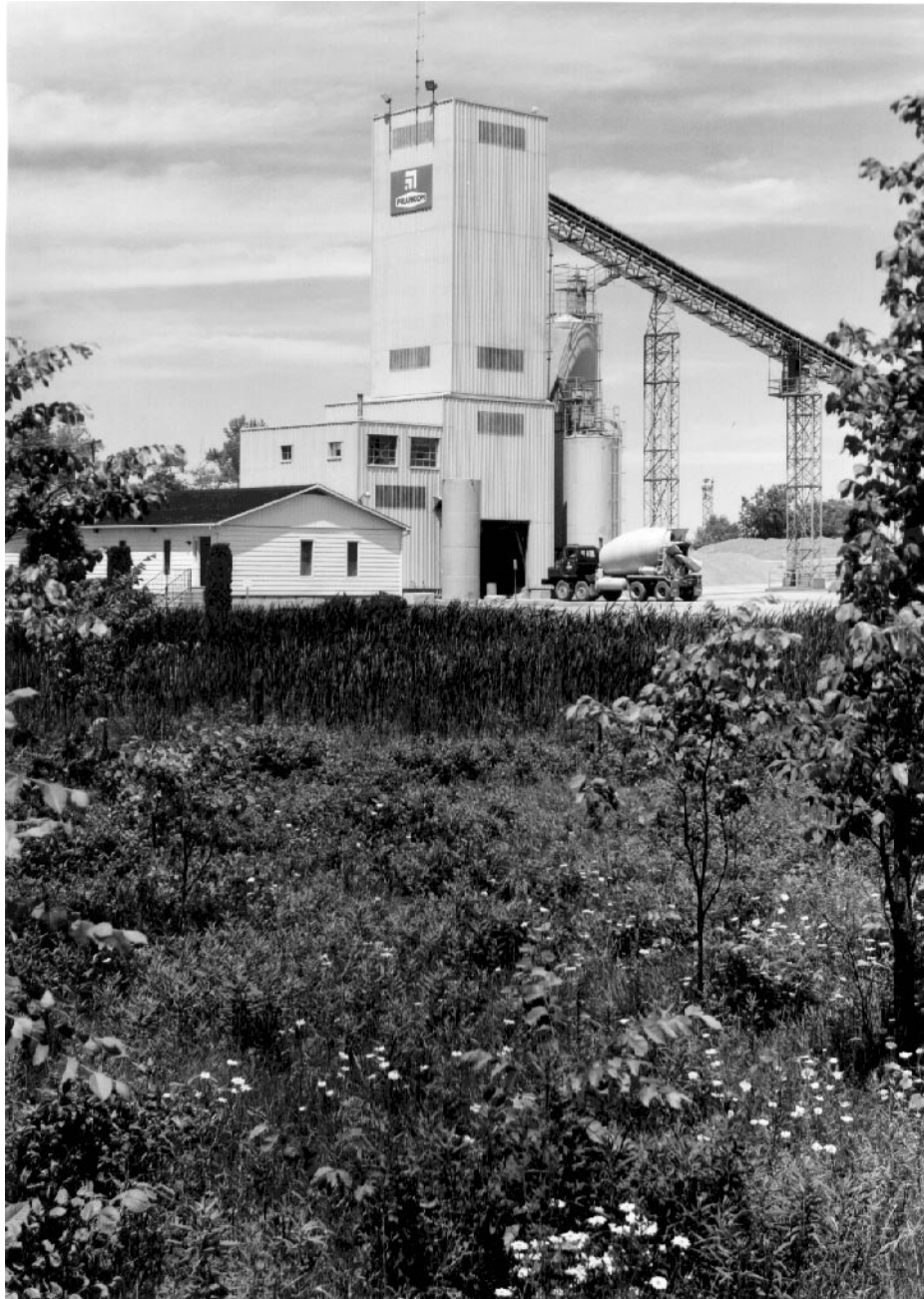


FIGURE 48: *Here's my photograph of the Francon Cement Plant, taken as described in this chapter. Depth of field extends from the floor of the marshy ground to the top of the tower as required. The f-stop used was f/22.*

As can be seen from Figure 47, I expect the plane of sharp focus to lie at an angle of about 80° to the vertical. The camera will be level, with its back vertical. In order to get the daisies sharp, I want the plane of sharp focus to pass about 8 ft. below the camera lens.

Step 1 is to mount the camera on the tripod and level it.

Step 2 is to set the lens tilt. The camera back is vertical, so I need to know the vertical distance from the plane of sharp focus to my lens. As noted earlier, that distance is 8 ft. or 96 inches. To find the required tilt I consult Table IIIb where I find that for $J = 8$ ft., α must be 5.65° . Alternately, I can calculate $J/f = 96/9.5 = 10.1$, and go directly to the depth of field tables. Anyway, the required lens tilt is about 6° . My old B&J doesn't have a tilt scale, so I use a protractor to measure 6° tilt—downwards.

Step 3 is to open the lens and examine the ground glass. I know that under these conditions the depth of field is going to be nearly equally distributed about the plane of sharp focus, so I rack the camera back so that the tower is in focus half-way up. I am done focusing! I don't know that the plane of sharp focus is inclined by exactly 80° , but, as the depth of field tables will show, depth of field is not highly sensitive to this angle: $80^\circ \pm 5^\circ$ is a sufficiently good estimate to use in consulting the table.

Step 4 is to determine what f-stop is necessary to keep the top of the tower as well as the base adequately in-focus. I guess the old favourite, $f/22$, and consult Table XIII. For $J/f = 10$ and $\Phi = 80^\circ$, the table tells me that the depth of field fractions are 0.133 on the near (upper) side, and 0.143 on the far or lower side. The total depth of field fraction is $0.133 + 0.143$ or 0.276. 300 ft. times 0.276 is 82.8 ft. That is just enough to encompass the tower and even the radio antenna on top of it. I was lucky; I guessed right. If I had guessed $f/32$, I would have found that the depth of field for that f-stop is 129 ft.—somewhat more than necessary. Similarly, at $f/16$ it would have been an inadequate 60 feet.

(I should point out here, that the depth of field I have calculated is really given perpendicular to the plane of sharp focus, whereas the tower is vertical. Thus the vertical depth of field is actually slightly different from that I have calculated here. Unless the difference in angles is more than about 25° , the error is not worth worrying about.)

Step 5 is to use my exposure meter to determine what shutter speed to use with $f/22$.

Step 6 is to close the shutter, set the aperture and shutter speed, insert the film holder, remove the dark slide, trip the shutter etc.—you know the procedure well.

Examination of Figure 48 will show that it all worked as expected.

A study of the depth of field tables will show that whenever the depth of field fractions are less than about 0.2, and whenever the plane of sharp focus is at about 90° to the film plane, the depth of field is nearly symmetrical—at any f-stop. You may also notice that when Φ is greater than 90° , the depth of field on the near side of the plane of sharp focus is greater than that on the far side! This last situation never happens with normal cameras. Beware the one-third rule!

Now let's look at this example critically. What should I expect to be able to resolve in the image? We'll use the object field method here. The working lens diameter is $241/22 = 11$ mm (approximately). For Φ angles near 90° , the distances **D** and **J** are just about equal. Thus I am on reasonable ground in using **D** = 8 ft. At the top of the tower, the resolution spot size will be 11 mm times 35 divided by 8, or 48 mm. Those figures "35" and "8" represent half the height of the tower and the distance **D** respectively. 48 mm is about 2 in. Thus I expect this image to resolve objects no smaller than that size at the top or bottom of the tower. Careful examination of the print shows that the radio antenna at the top of the tower is just resolved. The mast is probably about 4 in. to 6 in. in diameter, and the antenna elements are probably made from tubes no larger than about an inch or an inch and a half. The mast should show good contrast—and it does. The antenna elements should not show full contrast, and they don't. They are just about at the limit of being observable; they are on the verge of fading out.

At the daisy end of the photograph, I need resolution of no worse than about 3 mm in order to ensure that the daisies look reasonably sharp. My depth of field for that resolution is about 8 ft. times 3 mm divided by 11 mm —or about 2 ft. Close examination of the daisies shows them to be adequately sharp; the bushes and trees in the foreground do show out-of-focus effects wherever they rise more than two or three feet above the plane of sharp focus.

If you follow the arithmetic closely, you will observe that if I had focused farther away, made **D** and **J** larger, the radio antenna would have been sharper. Not only that, the tops of the trees in the foreground would have been sharper too. Let's examine the antenna situation. Suppose I had made the distance **J** (and therefore **D**) equal to 16 feet instead of 8 feet. We would do this by using 3° lens tilt instead of 6° . The resolution spot size at the top of the tower would have been 11 mm times 35 divided by 16, or 24 mm. Doubling the distance **D** has halved the resolution spot size at the top of the tower. At the daisies, however, the spot size would have increased to an unacceptable—but not terrible—5.5 mm. We would still see flowers there, and we might even be able to identify them as daisies. The object field method offers advantages whenever a critical determination is needed as to whether a specified object will be resolved or not.

Figure 49 shows the revised limits of the conventional depth of field when using 3° lens tilt with no change in the angle Φ . We can go even further,

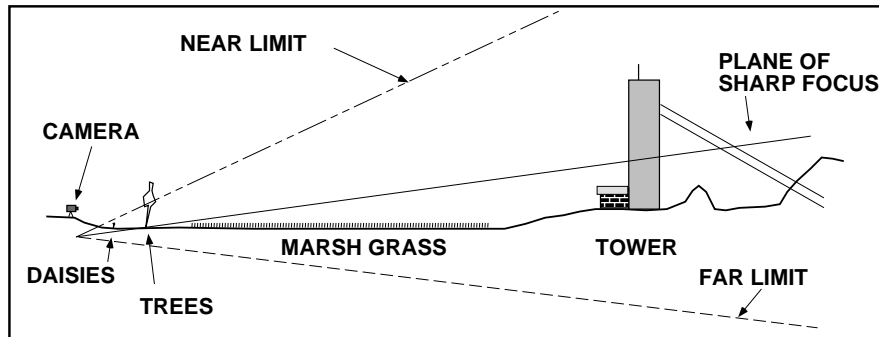


FIGURE 49: *Here's what would have happened if I had used half as much lens tilt, pushing the distance J out to 16 feet. Depth of field almost everywhere would have been greater! By further increasing J to 24 feet and decreasing Φ , even the tree tops would have been in acceptable focus—see Figure 33.*

changing the lens tilt to 2° and reducing Φ to 70° . The results are shown in Figure 50. Clearly focusing farther away would increase the depth of field everywhere that matters. Resolution at the top of the tower would be great, but at the base of the tower, it would be less so. Still, it should be slightly better than in the first case—the one I actually used.

Finding the optimum set-up to maximize depth of field is not easy. There can be several alternatives. The graphical method described in the previous chapter may help to outline the possibilities. Generally, the smaller the amount of lens tilt used, the greater will be the depth of field. To minimize depth of field, use significant angles of lens tilt to bring the plane of sharp focus close to the lens.

Focusing farther away helps resolution whenever the objects being considered lie on the camera side of a plane through the lens, parallel to the

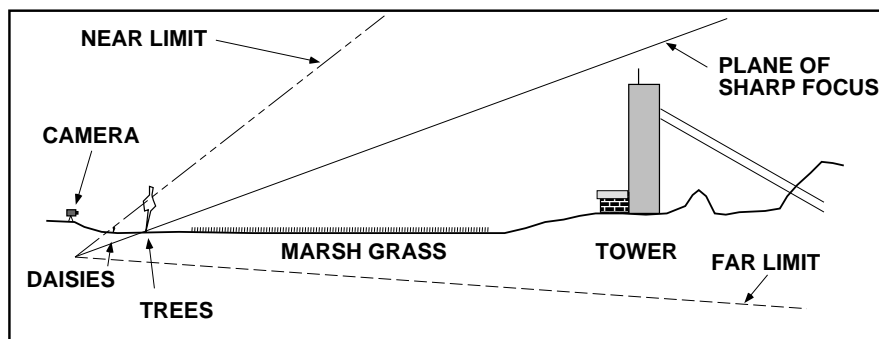


FIGURE 50: *Here's the situation with $J = 24$ feet, and $\Phi = 70^\circ$. The trees are just about covered. We have a new problem, however: we don't have a clear target to focus upon to set Φ .*

plane of sharp focus. (This plane is essentially the parallel-to-plane of sharp focus plane defined in Chapter 4.) Curiously, when an object lies right on the plane, focusing nearer or farther make no difference whatsoever. And, for objects on the far side of the plane, the closer we focus to the objects, the more sharply they are rendered.

I hope this chapter has been helpful in understanding how to apply the methods presented in this booklet. The examples were chosen because they are relatively straight forward. Things get somewhat more complicated if both swing and tilt are necessary. The example used here, focusing on a nearly horizontal plane, is probably the easiest one to try, and to solve. It's probably wise to start with the simple problems. After you master them, you can then extend the methods to the more difficult cases.

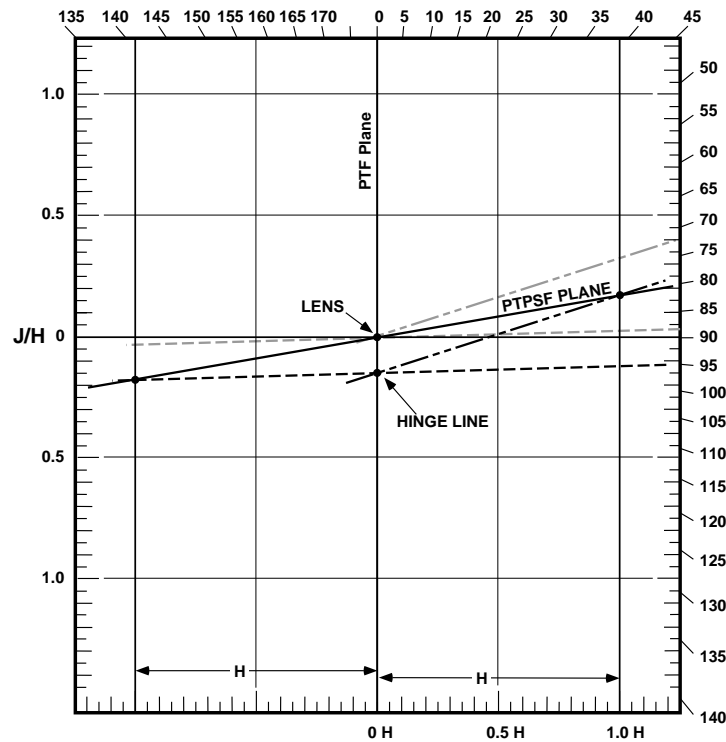


FIGURE 51: Here's our depth of field chart reproducing the conditions of this example in Chapter 8. The hinge line is 0.15 hyperfocal distances below the lens. The near limit of depth of field is given by the black dash-double-dot line; the far limit is given by the dashed line. In order to read the angles of these lines, we must draw parallel lines through the lens position: shown here by the gray lines.

Chapter 9

TUTORIAL

A challenging three-dimensional problem was presented to me by Craig Bailey of Alvin, Texas. The camera, positioned perhaps three feet above the ground, views a pathway passing through a gate. The gate is moderately close to the camera: about seven feet away. The path itself extends from the extreme foreground to the distance, but always at ground level. If the problem were just to focus on the pathway, the solution would be easy—for a view camera. We would simply set the lens tilt to give a distance, J , equal to the height of the lens above the path, then focus on the path—any part of it. The gate, however, extends from ground level to perhaps five feet above ground level. And in the background are bushes and trees between ground and a significant altitude. Figure 52 sketches a “side elevation” view of the situation. Can we use lens tilt to good effect under these conditions? This problem poses an interesting set of problems. Solving it should prove instructive. This chapter illustrates the process one might go through in the course of analysing the situation. It also serves to demonstrate the relationship between what we have learned so far and the depth of field situation for cameras with non-tilted lenses.

Considerations

To obtain standard perspective for the gate and other vertically oriented objects, the film plane must be oriented vertically. This prevents the gate posts from pointing in towards one-another or from splaying apart in the image. The main three-dimensional object in the foreground is the gate. Since the depth of

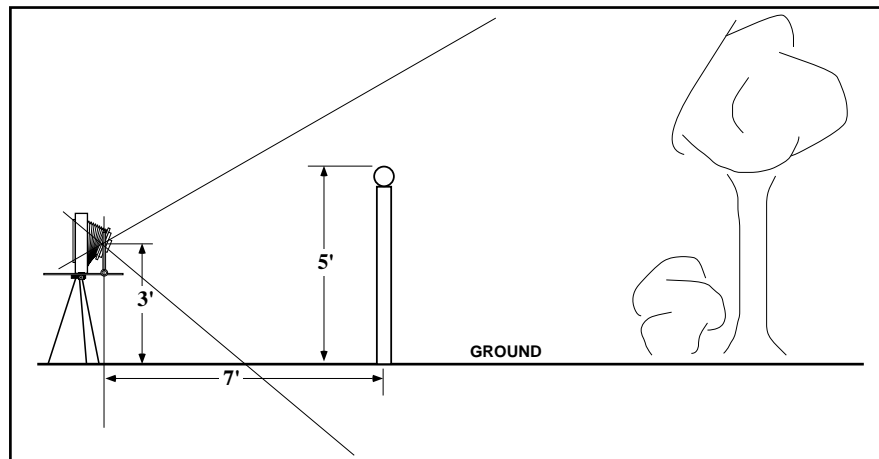


FIGURE 52: *Here's a side elevation view of the problem posed to me by Craig Bailey of Alvin Texas.*

field in the vertical direction (parallel to the film) is equally distributed about the plane of sharp focus, a first guess is that the plane of sharp focus should pass through a line half-way up the gate posts. But what value of J (or lens tilt) should be used? To answer this, we must understand what happens to depth of field as the plane of sharp focus pivots, not about the hinge line, but about a line half way up the gate posts.

Perhaps we should not bother with lens tilt at all; we might consider just setting focus at the hyperfocal distance. Figure 53 shows the plane of sharp focus and near limit of depth of field for the case of no lens tilt. Here the camera is simply focused at the hyperfocal distance (12.1 ft.) for its 90 mm lens at $f/22$. The far limit of depth of field is at infinity. Alternatively one might focus on the gate posts, giving rise to the limits of depth of field shown in Figure 54. I've used the symbols Z_o , Z_n , and Z_f to denote the distance at which the lens is focused, the near limit of depth of field and the far limit of depth of field respectively.

If we focus at the hyperfocal distance, the gate is within the established limits, but not the path in the foreground. If we focus on the gate posts, the path is sharpened but the nearest bits of it will still not be quite as sharp as desired. And anything beyond the tree shown will be noticeably out of focus.

Let's reconsider tilting the lens. Using the principles illustrated in Figure 45, we can sketch the limits of depth of field for a number of candidate tilted-lens situations. Two such possibilities are shown in Figure 55.

Figure 55 clearly illustrates that if the distance J is reduced from 5 feet to 3 feet (by increasing lens tilt), the region of acceptable definition—the space between the near and far limits of depth of field—shrinks noticeably. To

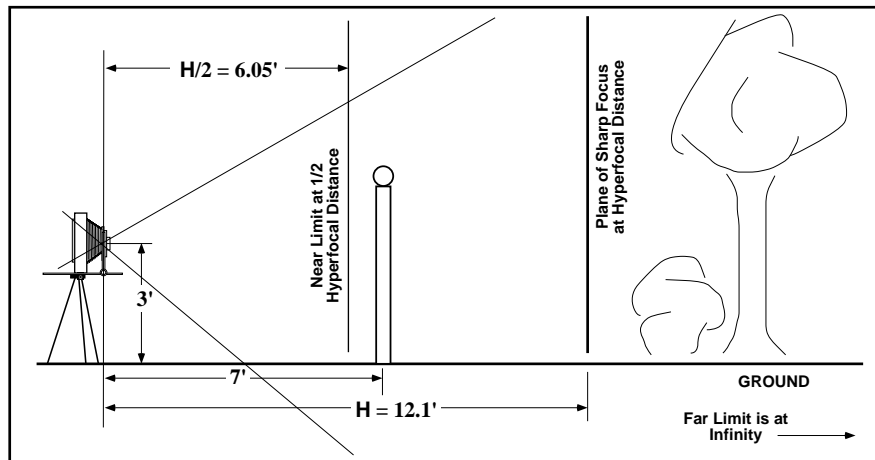


FIGURE 53: Using an aperture of $f/22$ with a non-tilted 90 mm lens yields the depth of field situation shown above if the lens is focused at the hyperfocal distance. Objects in the distance fall within acceptable limits, but the path in the foreground does not.

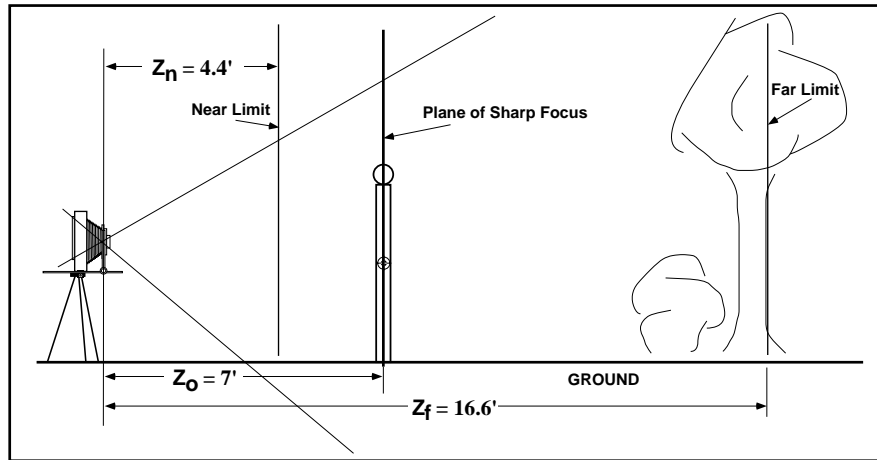


FIGURE 54: Using an aperture of $f/22$ but focusing on the gate posts yields too little depth of field at near and far distances.

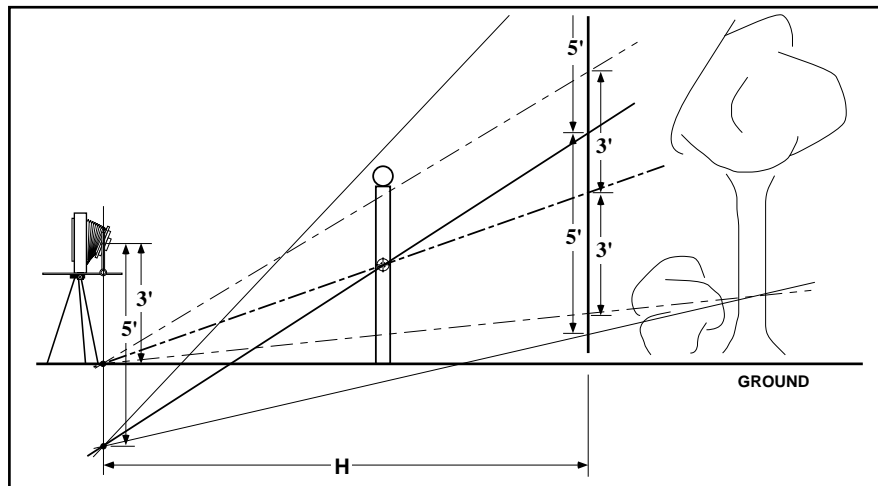


FIGURE 55: Tilting the lens forward by 3.3° or 5.6° yields the depth of field limits indicated by the solid and dashed lines respectively. The aperture is $f/22$. Note that increasing the lens tilt decreases depth of field.

maximize depth of field, one must minimize lens tilt. Yet tilting the lens can still be valuable for sharpening particular regions, such as the foreground.

As the sharp-eyed may have observed, Figures 54 and 55 are related. The place where the two near limits of depth of field cross in Figure 55 corresponds to the near limit of depth of field in Figure 54. And the same is true for the far limits. Furthermore, these two points of intersection, and the spot where the plane of sharp focus pivots, all lie along a straight line through the lens. This is not an accident. When the plane of sharp focus is rotated about a fixed point in the object field—by both tilting the lens and adjusting the

lens-to-film distance—the near and far limits of depth of field, along a ray through that fixed point, cannot change significantly. The principle at work here is that depth of field is related only to the focal length, the aperture, the allowable circle of confusion diameter, and the distance at which the lens is focused. The depth of field, along a ray from the lens to a fixed point constrained to be in focus, cannot change just because the lens is tilted.

In the problem at hand, we choose to hold focus on a point half-way up the gate post. This ensures that both ends of the post will be acceptably and equally sharp.

The procedure for plotting depth of field is simple. First we select the point in the object space where we want the plane of sharp focus to pivot. After any camera adjustments we will always focus again on this spot. Let's call this spot "point **P**". Then we draw (or imagine in our minds) the near and far limits of depth of field using classical techniques for untilted lenses. For this purpose the camera is presumed to be focused at a distance equal to the lens-to-pivot point distance (measured in a direction perpendicular to the film plane). Then we draw, or imagine, a ray from the lens to point **P** and beyond. Where this ray intersects the near and far limits of depth of field indicates the pivot points for these planes. We'll call these pivot points "point **C**" for the near or close limit of depth of field, and "point **F**" for the far limit of depth of field.

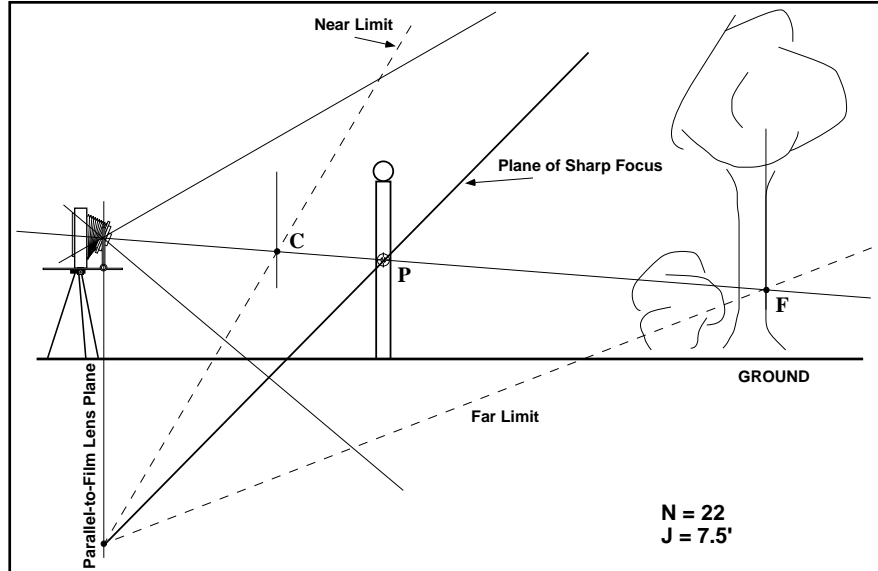


FIGURE 56: Using **J** equal to 7.5 feet (2.3° lens tilt) and $f/22$ solves the foreground problem, but falls short of giving the desired result for objects in the distance. The base of the tree is outside the permissible limits. The points **C** and **F** are at the limits of depth of field for a non-tilted lens focused on point **P**.

But we also know that, for a tilted lens, the near and far limits of depth of field must pass through the hinge line. These facts tell us everything we need to know. In our drawing, the near limit of depth of field extends from the hinge line to point **C** and beyond. Similarly, the far limit of depth of field extends from the hinge line through point **F**. As we adjust lens tilt, always readjusting the lens-to-film distance to keep the plane of sharp focus passing through point **P**, the hinge line moves along the Parallel-to-Film Lens Plane. Figure 56 illustrates the depth of field limits for a **J** distance of 7.5 feet and for $f/22$. With this set-up the foreground and gate post should be in focus, but the base of the tree will not be. But, as a first try, we're not far off.

(Before proceeding further, one might note that as lens tilt is adjusted towards zero, the distance **J** goes to infinity, and the limits of depth of field become parallel to the film plane. Thus the approximate method described here for view cameras is quite in accord with the traditional theory for non-tilted lenses.)

The problem now is to refine the positions of the hinge line and the points **C**, **P** and **F** to best achieve our goal.

A Solution

Applying this knowledge to the problem of the gate posts, we can make the following statements. Point **P** should be half-way up the gate posts, as noted earlier. Now we have just two things left to determine. We must choose an f-number and we must choose the lens tilt. The lens tilt is determined by the lens-to-hinge line distance, **J**. Point **C** must be such that the near limit of depth of field clears the tops of the gate posts. The hinge line will probably need to be somewhere near ground level. It can be below ground level provided the near limit of depth of field rises above the ground where the ground first comes into the camera's view.

The next step is to draw the near and far limits of depth of field for a lens focused at a distance of 7 feet, but for several apertures. We can do this using standard depth of field tables, or formulae. If we use **Z** to denote distance in front of the lens, measured in a direction perpendicular to the film plane, the appropriate formulae are, for the near limit:

$$Z_n = Z_o H / (Z_o + H)$$

and for the far limit:

$$Z_f = Z_o H / (H - Z_o).$$

H denotes the hyperfocal distance for whatever criteria we choose, while **Z_o** indicates the distance to the selected "point P". In this example **Z_o** is 7 feet. For a 90 mm lens on a 4 by 5 camera, we'll assume the hyperfocal distance is equal to 900 lens aperture diameters. This corresponds to a circle of confusion diameter equal to 0.1 millimeters or 1/1500 of the format diagonal. Figure 49 shows the positions of the limits so calculated, marked along the line from lens to point **P**, for various apertures. Table 1 provides the numbers appropriate to the problem at hand.

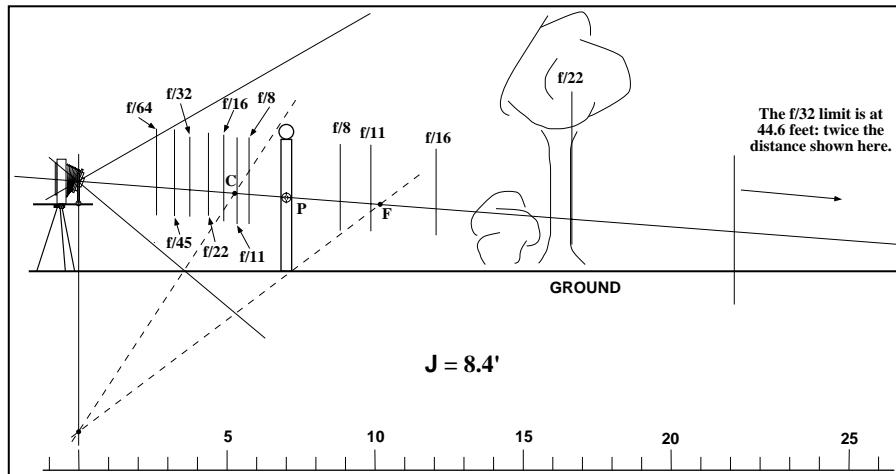


FIGURE 57: We can estimate the depth of field situation for a number of f -stops simultaneously by plotting the limits of standard depth of field for several apertures. An aperture just a bit smaller than $f/11$ is sufficient to solve the foreground problem so long as J is at 8.4 feet. But $f/11$ is far short of what is needed to sharpen objects at ground level in the distance. (Distance scale at bottom is in feet.)

f-Stop	H	Z_n	Z_f
2.8	94.9	6.5	7.6
4	66.4	6.3	7.8
5.6	47.5	6.1	8.2
8	33.2	5.8	8.9
11	24.2	5.4	9.9
12	22.1	5.3	10.2
16	16.6	4.9	12.1
22	12.1	4.4	16.6
27	9.8	4.1	24.2
32	8.3	3.8	44.6
38	7.0	3.5	-7382.8
45	5.9	3.2	-37.8
64	4.2	2.6	-10.2
90	3.0	2.1	-5.1

TABLE 1: This Table shows Hyperfocal Distances in feet for various f -stops as well as the near and far limits of depth of field for a non-tilted 90 mm lens focused at 7 feet.

A line from the top of the gate post, through the nearest bit of ground that can be seen by the camera, indicates that the distance J should be no greater than 8.4 feet. If J is greater than 8.4 feet, the near ground and the top of the post cannot both be in acceptable focus. The construction also indicates that an f -stop a bit smaller than $f/11$ could be used to solve the foreground problem. But, as shown in the figure, $f/11$ leaves things in the distance much

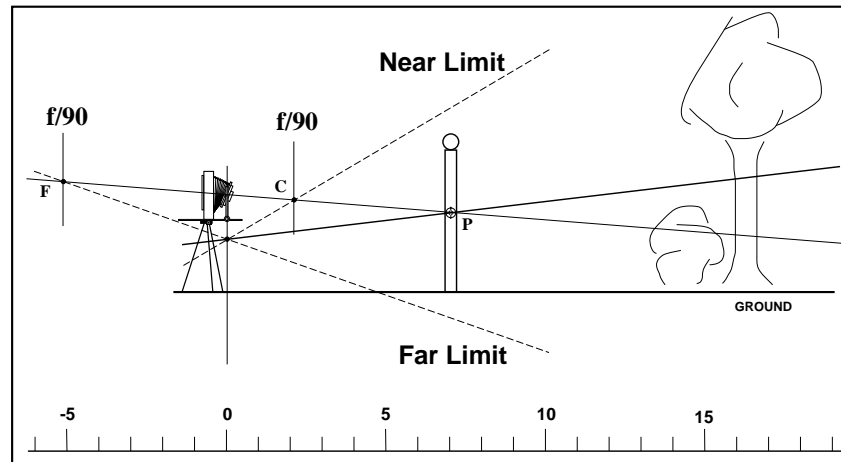


FIGURE 58: When point **P** is beyond the hyperfocal distance for the aperture under consideration, the point **F** lies behind the camera! The situation is illustrated here for $f/90$ and a lens tilt of 12° . Even $f/90$ fails to supply enough depth of field if too much lens tilt is used.

outside the far limit of depth of field. In order for objects in the extreme distance at ground level to be sharp, the hinge line must be at the same level as, or above, the appropriate point **F** for the aperture chosen. This ensures the far limit of depth of field will slope downwards away from the camera. Re-examination of Figure 56 will illustrate that even $f/22$ is not sufficiently small to guarantee such an outcome. Decreasing **J** helps sharpen objects in the extreme distance, but worsens matters at, for example, the base of the tree. With the camera position chosen, it might appear that a very small aperture will be needed. A higher camera position might be called upon to alleviate the problem substantially. The higher lens position would both raise point **C** and depress point **F**. But it also may not give us the image composition desired. Let's not sacrifice composition.

At first thought, it may appear that the far limit of depth of field can never be depressed below the angle of the line from lens to point **P**. It might seem that for point **F** at infinity or beyond, the far limit of depth of field is parallel to this line. For point **F** precisely at infinity, this is true. But in those cases where the hyperfocal distance, **H**, is less than the distance, **Z_o**, the formula indicates a negative value for **Z_f**! For **H** less than **Z_o** we have to plot point **F** behind the camera! Figure 58 shows this situation, using $f/90$ as an example. We now see that a reasonable aperture might permit us to achieve our goal.

All in all, it looks reasonable to use about $f/27$, yielding the situation depicted in Figure 59. The distance **J** is 5.5 feet, corresponding to a lens tilt of about 3° . We may still have a problem with objects at ground level beyond the tree. If such elements of the image are important we will have to use $f/32$. The set-up shown in Figure 59 puts the plane of sharp focus through the extreme foreground, the centers of the gate posts, and through the top of the tree. This factor should help make the image appear very sharp "from top to bottom".

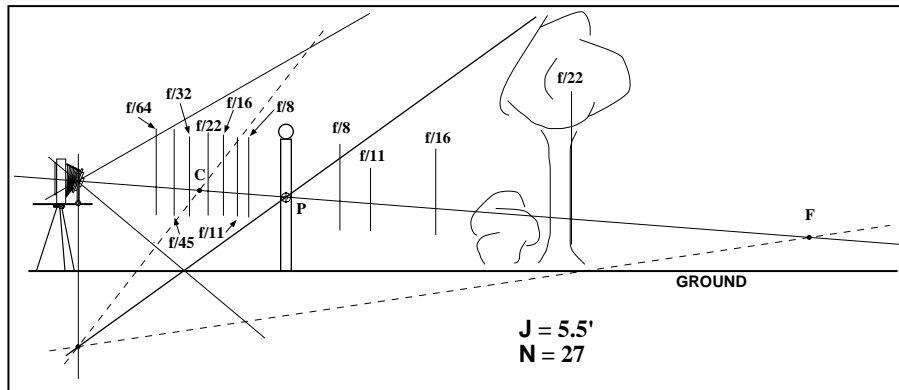


FIGURE 59: A reasonable compromise set-up might be $f/27$ with J equal to 5.5 feet (lens tilt of 3°). Objects at ground level beyond the tree may be just a bit fuzzy, however. Using $f/32$ would probably sharpen the image of distant objects if that were necessary.

We might also have kept our lens set to $f/38$ with the tilted lens. In this case *all* the important elements of our image would have been *well within* the limits for depth of field. Figure 60 shows this example. The penalty for using $f/38$ would be poorer definition in the sharpest parts of the image, due to diffraction.

Additional Comments

It is difficult to provide instant answers on how to best set-up for a view camera if the important elements of the subject being photographed are not naturally arranged along a plane. There are, however, relatively simple geometric principles that can be used to sketch the depth of field situation and

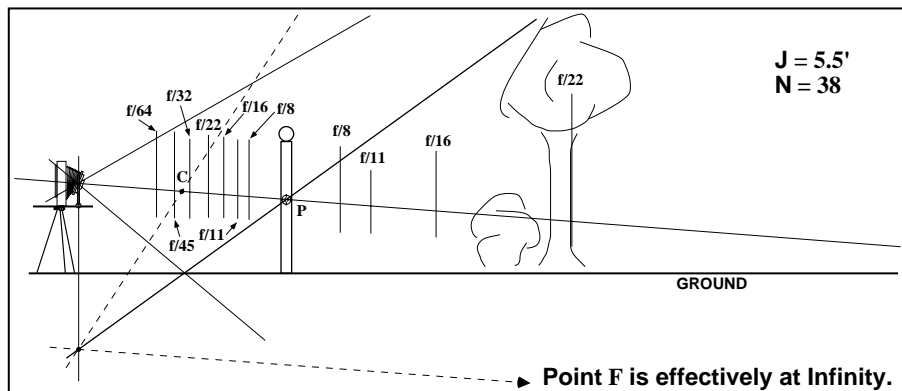


FIGURE 60: Another solution might have been to use $f/38$. With this aperture every element of our image is well within the depth of field limits. Without lens tilt, the near limit of depth of field would have coincided with the foreground. Yes, using lens tilt gives us a sharper picture!

help the photographer decide what might be best for the situation at hand. One example has been examined here to illustrate these ideas.

In the example studied here, we could have used the standard “focus at the hyperfocal distance” rule to maximize depth of field. The result would have been that we would have had to use about $f/38$ and only the gate posts would have been in critical focus. By tilting the lens 3° we have put the extreme foreground, the gate posts and the top of the tree in critical focus, and, we could open the lens by one stop. The penalty is that objects at ground level beyond the tree will tend to be just a bit soft. Then again, maybe this will tend to emphasize depth in the final image.

In real shooting situations there is seldom a need for precise calculations. Estimates of distance are usually good enough to provide the insight necessary, and guide the procedure to be followed. I carry with me a table of lens tilts and **J** distances for various lenses, and a similar table of hyperfocal distances. These guide my determination of the desired lens tilt, which is then set with the aid of a protractor. The final adjustment is done simply by using the ground glass to set focus on the selected “point **P**”. I doubt that I can set the lens tilt more accurately than perhaps on-half of a degree. Thus I really don’t know the value of **J** to better than perhaps six inches at best. What I do know, is that I could not set the camera as accurately if I were to set the lens tilt by trial and error!

Other Ways of Illustrating Depth of Field

The simple relationships just described will allow us to draw a depth of field diagram for multiple f-stops, but one orientation of the plane of sharp focus and one **J** distance. An example is shown in Figure 61. It will be seen that depth of field measured parallel to the film plane scales directly as the f-number. The depth of field measured this way for $f/32$ is twice that for $f/16$ and so on. (The significance of lines drawn parallel to the film plane is that image magnification is constant for any object along such a line.)

We do not always need the same degree of definition at every point within the “sharp” part of our image. Can we determine quantitatively what the circle of confusion will be for any object in the scene being photographed? The simple relationships between depth of field and hyperfocal distance, and between hyperfocal distance and circle of confusion diameter, make the problem easy. Depth of field is one-third as great if we use one-third the original circle of confusion diameter. It is four times as great for four times the circle of confusion diameter and so on. This simple scaling allows us to draw a “contour map” of the circle of confusion diameter for any point in the object field. In fact such a “contour map” of circle of confusion diameters for a single f-stop is just a re-labeled version of Figure 61. An example is illustrated in Figure 62.

We can go one step farther here by also indicating the zone for which the lens definition will be limited by diffraction: the gray area in Figure 62. The smallest circle of confusion a lens can produce is limited by diffraction to about

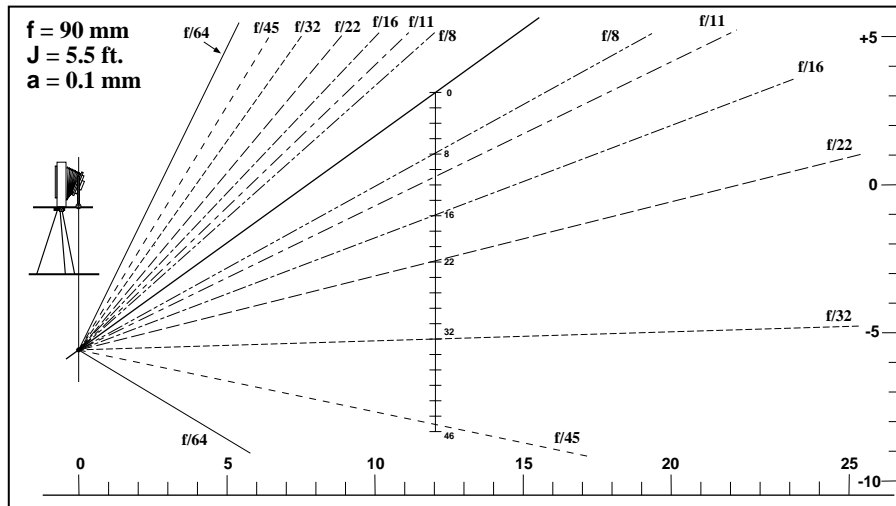


FIGURE 61: We can show the depth of field for a number of apertures simultaneously, as shown here. Details of the scene have been removed to reduce the clutter. The horizontal and vertical scales (along the edges) are in feet. Optical conditions and distances in this diagram are the same as those used in Figure 60. The center scale shows that the vertical depth of field scales directly as the f -number of the lens.

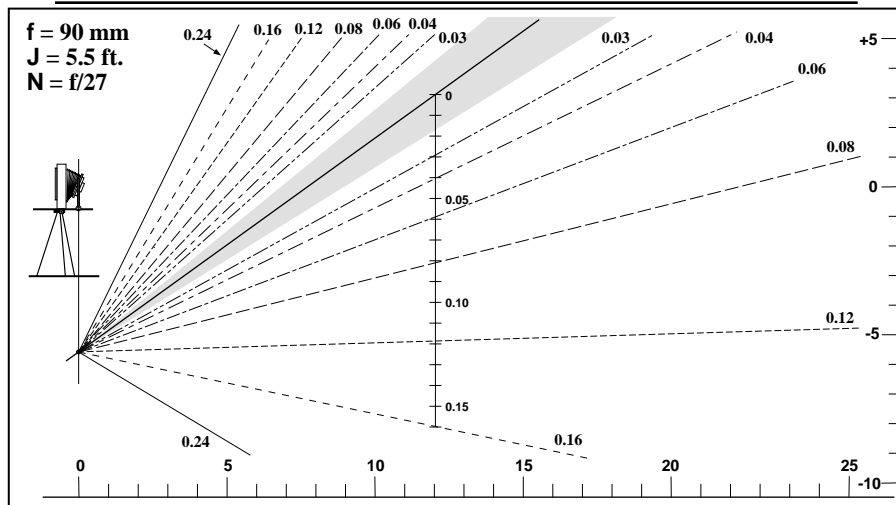


FIGURE 62: The very same drawing used for Fig. 61 can be re-labeled to map out the circle of confusion diameters (measured at the image) for any point in the scene. The numbers represent the diameter of the circle of confusion, in millimeters, for an aperture of $f/27$. The vertical scale in the center has been adjusted to measure the diameter of the circle of confusion at the film. The gray area shows the region for which the lens will be diffraction limited.

N/1600 mm where **N** is the f-number. That limiting diameter is about 0.017 mm at f/27 or 0.025 mm at f/38. These figures are about one-sixth to one-quarter the limit we set for depth of field purposes.



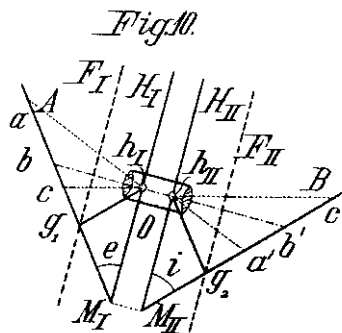
Who was Scheimpflug?

Captain Theodor Scheimpflug was an Austrian Army and Naval officer who was keen to use aerial photography employing balloon-suspended cameras to make accurate maps. In order to do this he needed to be able to distort the photographs so as to undo the natural distortion that arises when the camera is not looking straight down. He was born on 7 October 1865 and died on 22 August 1911.

In 1904 he obtained a British Patent describing a number of methods for accomplishing his intended tasks. In this patent he lays down three optical principles, the first of which is the rule that normally carries his name. Perhaps surprisingly, however, he attributes this rule to the French camera maker Jules Carpentier. His second principle describes what I have called the Hinge Rule as well as the Reciprocal Hinge Rule. The third principle deals with the use of multiple lens and/or mirror systems.

His ideas are still used today, not only in view camera photography but also in ophthalmology (treating and attending to diseases of the eye) and photogrammetry (map-making from aerial photographs).

Above is a portrait of Theodor Scheimpflug dating from about 1895. Below is one of his patent drawings describing his principles as they apply to a single thick lens.



Chapter 10

SUMMARY

After assembling this information, I looked back and thought: “This is an awful lot of stuff. What message do I wish to leave with view camera photographers?” This last chapter is intended to reinforce just the essential bits.

The Main Message

Point number 1 is that focusing the view camera can be speeded up considerably by employing the hinge rule. The process consists of the following:

1. Orient the camera back and the lens position to give the desired perspective and angle of view.
2. Determine where the plane of sharp focus is to lie, and estimate distance from the lens to the plane of sharp focus, measured in a direction parallel to the film plane. This is the distance, **J**.
3. Use Table III to determine the required amount of lens tilt, based upon the focal length of the lens and the distance **J**. **J** cannot be less than one focal length.
4. Tilt the lens towards the intended plane of sharp focus by the amount indicated in the previous step.
5. Viewing the ground glass, rack the camera back to place the plane of sharp focus in the proper position, that is, at the proper angle.

You should now be finished focusing.

Point number 2 is that estimating depth of field for view cameras is indeed possible. I have provided tables here that provide two ways to measure it: as angles of coverage, and as depth of field fractions. These fractions tell you how great the depth of field is, measured in a direction perpendicular to the plane of sharp focus. The actual depth of field is that fraction times the lens-to-plane of sharp focus distance (measured perpendicular to the film plane) at the point of interest.

Point number 3 is that it is not in fact necessary to work with tables. There is a depth of field method simple enough to carry around in your head. If we talk in terms of depth of field fractions for depth of field, measured in a direction parallel to the film plane, that depth of field fraction is approximately

TABLE XIX: Table of Hyperfocal Distances for $a = f/1500$

f-number, N	FOCAL LENGTH (in millimeters)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
	Hyperfocal distances in meters														
2.8	28.4	34.9	40.3	48.3	53.7	56.4	61.7	64.4	72.5	80.5	96.6	112.7	128.8	161.0	241.5
4	19.9	24.4	28.2	33.8	37.6	39.5	43.2	45.1	50.8	56.4	67.7	79.0	90.2	112.8	169.2
5.6	14.2	17.5	20.2	24.2	26.9	28.2	30.9	32.3	36.3	40.3	48.4	56.5	64.5	80.7	121.0
8	10.0	12.3	14.1	17.0	18.9	19.8	21.7	22.6	25.4	28.3	33.9	39.6	45.2	56.6	84.8
11	7.3	8.9	10.3	12.4	13.7	14.4	15.8	16.5	18.5	20.6	24.7	28.8	33.0	41.2	61.8
16	5.0	6.2	7.1	8.5	9.5	9.9	10.9	11.4	12.8	14.2	17.1	19.9	22.7	28.4	42.6
22	3.7	4.5	5.2	6.2	6.9	7.3	8.0	8.3	9.3	10.4	12.5	14.5	16.6	20.8	31.1
32	2.5	3.1	3.6	4.3	4.8	5.0	5.5	5.7	6.5	7.2	8.6	10.1	11.5	14.4	21.5
45	1.8	2.2	2.6	3.1	3.4	3.6	3.9	4.1	4.6	5.2	6.2	7.2	8.2	10.3	15.5
64	1.3	1.6	1.8	2.2	2.4	2.6	2.8	2.9	3.3	3.7	4.4	5.1	5.9	7.3	11.0
90	0.9	1.1	1.3	1.6	1.8	1.9	2.0	2.1	2.4	2.7	3.2	3.7	4.2	5.3	8.0
	Hyperfocal distances in feet														
2.8	93.3	114.5	132.1	158.5	176.1	184.9	202.5	211.3	237.7	264.1	317.0	369.8	422.6	528.3	792.4
4	65.4	80.2	92.5	111.0	123.4	129.5	141.9	148.0	166.5	185.0	222.0	259.1	296.1	370.1	555.1
5.6	46.7	57.3	66.2	79.4	88.2	92.6	101.4	105.8	119.1	132.3	158.8	185.2	211.7	264.6	396.9
8	32.8	40.2	46.4	55.7	61.8	64.9	71.1	74.2	83.5	92.8	111.3	129.9	148.4	185.5	278.3
11	23.9	29.3	33.8	40.6	45.1	47.3	51.8	54.1	60.8	67.6	81.1	94.6	108.2	135.2	202.8
16	16.5	20.2	23.3	28.0	31.1	32.6	35.7	37.3	42.0	46.6	56.0	65.3	74.6	93.3	139.9
22	12.0	14.8	17.0	20.4	22.7	23.8	26.1	27.2	30.6	34.0	40.9	47.7	54.5	68.1	102.1
32	8.3	10.2	11.8	14.1	15.7	16.5	18.1	18.8	21.2	23.6	28.3	33.0	37.7	47.1	70.7
45	6.0	7.3	8.4	10.1	11.3	11.8	13.0	13.5	15.2	16.9	20.3	23.7	27.0	33.8	50.7
64	4.2	5.2	6.0	7.2	8.0	8.4	9.2	9.6	10.8	12.0	14.4	16.8	19.2	24.1	36.1
90	3.1	3.8	4.3	5.2	5.8	6.1	6.7	7.0	7.8	8.7	10.4	12.2	13.9	17.4	26.1

Hyperfocal distance, **H**, is the distance from the lens to the inner limit of depth of field when the lens is focused at infinity, with its axis perpendicular to the film. The hyperfocal distance also has utility when estimating depth of field at other distances and under tilted lens conditions. Chapter 6 showed you how to use it. In the table above, the exact formula for **H** is used : $H = f^2/g$.

J/H , where H is the standard hyperfocal distance. If we need to be exact, depth of field fraction is fJ/AH .

This tells us that at a distance of one hyperfocal distance, the depth of field, measured in a direction parallel to the film, is approximately J , or, if we need to be exact, fJ/A . At a distance of one-half the hyperfocal distance is (approximately) one-half of J . At five hyperfocal distances the depth of field is $5J$, and so on. This depth of field applies on each side of the plane of sharp focus. At a range of one hyperfocal distance the *total* depth of field is $2J$, etc.

It may be helpful to have a table of hyperfocal distances. One is provided at Table XIX.

Actually, hyperfocal distances are not that difficult to calculate approximately. If the maximum diameter of the circle of confusion is expressed as some fraction, $1/Q$, of the lens focal length, the hyperfocal distance is simply the actual lens diameter multiplied by Q . If the circle of confusion is $1/1500$ of the lens focal length, the hyperfocal distance is 1500 lens diameters. Again, we have something we can remember easily. We must be careful to use the right fraction for the lens and format we are using. For a 150 mm lens with a 4×5 camera, $1/1500$ may be about right. But if we are using a 90 mm lens with that same format, the appropriate number is probably $1/900$. That's because 0.1 mm is $1/1500$ of 150 mm, but $1/900$ of 90 mm.

Point number 4 is that depth of field is influenced by lens tilt. For a given set up, more lens tilt generally means less depth of field. It might mean depth of field distributed in a more useful way, however. Generally speaking, to maximize depth of field, we should use the minimum lens tilt that will achieve our purpose.

Point number 5 is that for critical work, the object field method of estimating depth of field may offer more precise information. No tables are needed, but we must remember for view cameras to measure the distance from lens to plane of sharp focus in a direction perpendicular to the plane of sharp focus. I have not described this method at length in this book. That is because the object field method was described in an earlier book, *The INs and OUTs of FOCUS*.

Point number 6 is that longer lenses require more tilt than short lenses for the same shooting geometry. The tables and approximate formulae show that for the same J distance, a lens twice as long requires twice the amount of lens tilt.

I have also provided you with a couple of blank forms (at the end of this chapter) for using the graphical method described in Chapter 7. There is even a slightly modified version of the form which permits fewer lines to be drawn.

Another question I asked myself was: "Why did I have so much trouble

focusing the view camera before?" I believe the answer is provided by Figure 63 on page 102. This graph tells me that focusing a view camera is something like driving a car on ice. In driving on ice, both steering wheel movements and throttle (gas pedal) position affect the direction in which the car will go. Sometimes turning the steering wheel to the right will make the car go to the right, but turning the wheel more to the right brings the car more to the left. I think lens tilt is like movement of the steering wheel, and back focus adjustment is like pressure on the gas pedal. Let's take an example. If the back focus distance is equal to 0.95 times the focal length, the first 5° of lens tilt result in almost 60° change in the angle Φ . The next 50° of lens tilt change Φ by 10° at most and bring me back to where I started! How much a certain amount of lens tilt affects the situation depends upon the position of the camera back. As I try to focus by juggling lens tilt and back position, the rules keep changing. Yes, just as Canadian drivers can learn to drive on ice, view camera photographers can learn how to deal with these interacting controls, but it isn't easy.

Other Reading

There is quite a lot I have not covered. There are other books on view cameras which describe many aspects of the view camera well; I leave those subjects to them. Below you will find a listing of other reading which you may find helpful.

Focus and depth of field for view cameras are subjects which I did not find to be covered in the detail I needed in any of these books and articles. And frequently one finds errors, or discrepancies between books. Depth of field is a topic seemingly fraught with ambiguity and misinterpretation. In part that's why I wrote *FOCUSING the VIEW CAMERA*.

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Melissa II

(Taken with a lens of about 240 mm, but not with a view camera!)



Detail from page 10

The photograph "Point Gatineau" on page 10 holds remarkable detail. Reproduced above is an enlarged portion showing detail of the church which features in the central upper portion of the original image. Windows that are not even visible in the page 10 reproduction can be seen to be composed in fact of three panes. The finest detail on the negative measures about 1/8000 of the format diagonal. This represents a five-fold improvement over the almost universal criterion the permissible diameter of the circle of confusion should be the diagonal of the format divided by 1500.

Chapter 11

TABLES

The remainder of this booklet consists of various tables which are intended to help the view camera user focus his or her camera and to understand the depth of field that results.

The tables are organized by function, with a brief introduction to each table type.

On page 87 is an index for finding the right table based on the black index tabs in the margins.

Note that some tables consist of more than one part. For example, separate tables may be offered for distances in feet and in meters. And the depth of field tables offer two descriptions of the zone of acceptable sharpness: by angle and by depth of field fraction.

The tables themselves may not be self-explanatory. Some of the concepts presented are new; unless you have read the chapter on optical principles, you may not understand the purpose of the table.

Some of the tables contain the notation “n/a”. This is short for “not applicable”. Usually the notation signifies a situation where the mathematical result would not be meaningful. The most usual circumstance is one where the that place in the table would cause the lens to try to focus inside its front focal plane: an impossible task.

Note:
Hyperfocal Distances

After the Tables section was originally typeset, I decided to add a table of hyperfocal distances for common focal lengths and f-stops. Table XIX appears on page 80, opposite the page on which it is first cited.

INDEX TO TABLES

TABLE I	Effective focal length, f' , for ray angle, δ	f' for δ
TABLES IIa, b	Lens and Hinge Line tilt for combined tilt and swing.	$\alpha-\theta$
TABLE IIIa	Tilt angle, α , required for distance, J (in meters).	α for J
TABLE IIIb	Tilt angle, α , required for distance, J (in feet).	α for J
TABLE IVa	Distance, J (in meters) for tilt angle, α	J for α
TABLE IVb	Distance, J (in feet) for tilt angle, α	J for α
TABLE Va	Value of J/f for distance J (in meters) and focal length, f	J/f
TABLE Vb	Value of J/f for distance J (in feet) and focal length, f	J/f
TABLE VI	Value of A/f for given J/f (or α) and Φ	A/f
	-Section includes graphs (Figures 36 and 37.)	
TABLES VIIa, b	Depth of Field for f/2.8	f/2.8
TABLES VIIIa, b	Depth of Field for f/4	f/4
TABLES IXa, b	Depth of Field for f/5.6	f/5.6
TABLES Xa, b	Depth of Field for f/8	f/8
TABLES XIa, b	Depth of Field for f/11	f/11
TABLES XIIa, b	Depth of Field for f/16	f/16
TABLES XIIIa, b	Depth of Field for f/22	f/22
TABLES XIVa, b	Depth of Field for f/32	f/32
TABLES XVa, b	Depth of Field for f/45	f/45
TABLES XVIa, b	Depth of Field for f/64	f/64
TABLES XVIIa, b	Depth of Field for f/90	f/90
TABLE XVIIIa, b	Distance D for distance J and angle Φ	D
TABLE XIX	Hyperfocal distance H (in feet and meters)	H

TABLE OF EFFECTIVE FOCAL LENGTHS

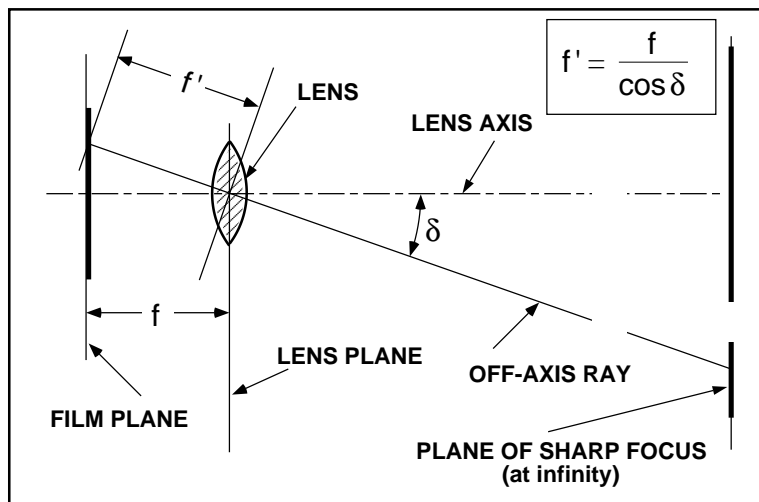
Table I at right tells you the effective focal length of a lens for rays passing through the lens at the angle (measured from the lens axis) as indicated in the left-most column.

The remaining column headings give the nominal focal length of the lens: that is, its focal length for rays entering the lens parallel to its axis. The column headed "1" can be used for focal lengths other than those shown.

Examples:

We wish to know the effective focal length for a ray passing through a 47 mm lens at an angle of 15° . Opposite 15° and under the "1" column, we find the number "1.04". This means that for rays of 15° , the effective focal length of a lens is 1.04 times its nominal value. In this case, $1.04 \times 47 = 48.88$ mm.

For a focal length listed, say 210 mm, we need only look up the number under the appropriate columns. For a lens of 210 mm nominal focal length, the effective focal length for a 15° ray is 217.41 mm.



The effective focal length, f' , is shown here for an oblique ray, making angle δ with the lens axis.

TABLE I: EFFECTIVE FOCAL LENGTH

Angle off axis (in degrees)	FOCAL LENGTH (in mm)															
	1	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.2	1.00001	53.00	65.00	75.00	90.00	100.00	105.00	115.00	120.00	135.00	150.00	180.00	210.00	240.00	300.00	450.00
1	1.0002	53.01	65.01	75.01	90.01	100.02	105.02	115.02	120.02	135.02	150.02	180.03	210.03	240.04	300.05	450.07
5	1.004	53.20	65.25	75.29	90.34	100.38	105.40	115.44	120.46	135.52	150.57	180.69	210.80	240.92	301.15	451.72
10	1.015	53.82	66.00	76.16	91.39	101.54	106.62	116.77	121.85	137.08	152.31	182.78	213.24	243.70	304.63	456.94
15	1.04	54.87	67.29	77.65	93.17	103.53	108.70	119.06	124.23	139.76	155.29	186.35	217.41	248.47	310.58	465.87
20	1.06	56.40	69.17	79.81	95.78	106.42	111.74	122.38	127.70	143.66	159.63	191.55	223.48	255.40	319.25	478.88
22.5	1.08	57.37	70.36	81.18	97.42	108.24	113.65	124.48	129.89	146.12	162.36	194.83	227.30	259.77	324.72	487.08
25	1.10	58.48	71.72	82.75	99.30	110.34	115.85	126.89	132.41	148.96	165.51	198.61	231.71	264.81	331.01	496.52
27.5	1.13	59.75	73.28	84.55	101.46	112.74	118.38	129.65	135.29	152.20	169.11	202.93	236.75	270.57	338.21	507.32
30	1.15	61.20	75.06	86.60	103.92	115.47	121.24	132.79	138.56	155.88	173.21	207.85	242.49	277.13	346.41	519.62
32.5	1.19	62.84	77.07	88.93	106.71	118.57	124.50	136.35	142.28	160.07	177.85	213.42	248.99	284.57	355.71	533.56
35	1.22	64.70	79.35	91.56	109.87	122.08	128.18	140.39	146.49	164.80	183.12	219.74	256.36	292.99	366.23	549.35
37.5	1.26	66.81	81.93	94.54	113.44	126.05	132.35	144.95	151.26	170.16	189.07	226.89	264.70	302.51	378.14	567.21
40	1.31	69.19	84.85	97.91	117.49	130.54	137.07	150.12	156.65	176.23	195.81	234.97	274.14	313.30	391.62	587.43
45	1.41	74.95	91.92	106.07	127.28	141.42	148.49	162.63	169.71	190.92	212.13	254.56	296.98	339.41	424.26	636.40
50	1.56	82.45	101.12	116.68	140.02	155.57	163.35	178.91	186.69	210.02	233.36	280.03	326.70	373.37	466.72	700.08
55	1.74	92.40	113.32	130.76	156.91	174.34	183.06	200.50	209.21	235.37	261.52	313.82	366.12	418.43	523.03	784.55
60	2.00	106.0	130.0	150.0	180.0	200.0	210.0	230.0	240.0	270.0	300.0	360.0	420.0	480.0	600.0	900.0
65	2.37	125.4	153.8	177.5	213.0	236.6	248.5	272.1	283.9	319.4	354.9	425.9	496.9	567.9	709.9	1,065.
70	2.92	155.0	190.0	219.3	263.1	292.4	307.0	336.2	350.9	394.7	438.6	526.3	614.0	701.7	877.1	1,316.
75	3.86	204.8	251.1	289.8	347.7	386.4	405.7	444.3	463.6	521.6	579.6	695.5	811.4	927.3	1,159.	1,739.
80	5.76	305.2	374.3	431.9	518.3	575.9	604.7	662.3	691.1	777.4	863.8	1,037.	1,209.	1,382.	1,728.	2,591.
85	11.47	608.1	745.8	860.5	1,033.	1,147.	1,205.	1,319.	1,377.	1,549.	1,721.	2,065.	2,409.	2,754.	3,442.	5,163.
89	57.30	3,037.	3,724.	4,297.	5,157.	5,730.	6,016.	6,589.	6,876.	7,735.	8,595.	10,314.	12,033.	13,752.	17,190.	25,784.

f' for δ

TABLE IIa: TOTAL EFFECTIVE LENS TILT

SWING or TILT	TILT or SWING (in Degrees)														
	1	3	5	7	10	12	15	18	20	22	25	30	35	40	45
1	1.4	3.2	5.1	7.1	10.0	12.0	15.0	18.0	20.0	22.0	25.0	30.0	35.0	40.0	45.0
2	2.2	3.6	5.4	7.3	10.2	12.2	15.1	18.1	20.1	22.1	25.1	30.1	35.0	40.0	45.0
3	3.2	4.2	5.8	7.6	10.4	12.4	15.3	18.2	20.2	22.2	25.2	30.1	35.1	40.1	45.1
4	4.1	5.0	6.4	8.1	10.8	12.6	15.5	18.4	20.4	22.3	25.3	30.2	35.2	40.2	45.1
5	5.1	5.8	7.1	8.6	11.2	13.0	15.8	18.7	20.6	22.5	25.5	30.4	35.3	40.3	45.2
6	6.1	6.7	7.8	9.2	11.6	13.4	16.1	18.9	20.8	22.8	25.7	30.5	35.4	40.4	45.3
7	7.1	7.6	8.6	9.9	12.2	13.9	16.5	19.3	21.1	23.0	25.9	30.7	35.6	40.5	45.4
8	8.1	8.5	9.4	10.6	12.8	14.4	17.0	19.6	21.5	23.3	26.2	31.0	35.8	40.7	45.6
9	9.1	9.5	10.3	11.4	13.4	15.0	17.4	20.1	21.9	23.7	26.5	31.2	36.0	40.8	45.7
10	10.0	10.4	11.2	12.2	14.1	15.6	18.0	20.5	22.3	24.1	26.8	31.5	36.2	41.0	45.9
11	11.0	11.4	12.1	13.0	14.8	16.2	18.5	21.0	22.7	24.5	27.2	31.8	36.5	41.2	46.0
12	12.0	12.4	13.0	13.9	15.6	16.9	19.1	21.5	23.2	24.9	27.6	32.1	36.8	41.5	46.2
13	13.0	13.3	13.9	14.7	16.3	17.6	19.8	22.1	23.7	25.4	28.0	32.5	37.0	41.7	46.5
14	14.0	14.3	14.8	15.6	17.1	18.4	20.4	22.7	24.2	25.9	28.4	32.8	37.4	42.0	46.7
15	15.0	15.3	15.8	16.5	18.0	19.1	21.1	23.3	24.8	26.4	28.9	33.2	37.7	42.3	46.9
16	16.0	16.3	16.7	17.4	18.8	19.9	21.8	23.9	25.4	27.0	29.4	33.6	38.1	42.6	47.2
17	17.0	17.3	17.7	18.3	19.6	20.7	22.5	24.6	26.0	27.5	29.9	34.1	38.4	42.9	47.5
18	18.0	18.2	18.7	19.3	20.5	21.5	23.3	25.2	26.7	28.1	30.5	34.5	38.8	43.2	47.7
19	19.0	19.2	19.6	20.2	21.4	22.4	24.0	25.9	27.3	28.8	31.0	35.0	39.2	43.6	48.0
20	20.0	20.2	20.6	21.1	22.3	23.2	24.8	26.7	28.0	29.4	31.6	35.5	39.7	44.0	48.4
22	22.0	22.2	22.5	23.0	24.1	24.9	26.4	28.1	29.4	30.7	32.8	36.6	40.6	44.7	49.0
25	25.0	25.2	25.5	25.9	26.8	27.6	28.9	30.5	31.6	32.8	34.8	38.3	42.1	46.0	50.1
27	27.0	27.2	27.4	27.8	28.7	29.4	30.6	32.1	33.1	34.3	36.1	39.5	43.1	47.0	50.9
30	30.0	30.1	30.4	30.7	31.5	32.1	33.2	34.5	35.5	36.6	38.3	41.4	44.8	48.4	52.2
32	32.0	32.1	32.3	32.7	33.4	34.0	35.0	36.2	37.2	38.2	39.8	42.7	46.0	49.5	53.2
35	35.0	35.1	35.3	35.6	36.2	36.8	37.7	38.8	39.7	40.6	42.1	44.8	47.9	51.1	54.6
40	40.0	40.1	40.3	40.5	41.0	41.5	42.3	43.2	44.0	44.7	46.0	48.4	51.1	54.1	57.2
45	45.0	45.1	45.2	45.4	45.9	46.2	46.9	47.7	48.4	49.0	50.1	52.2	54.6	57.2	60.0

When both tilt and swing are used, the depth of field tables require a knowledge of the total effective amount of lens tilt. The above table gives the total effective tilt for various combinations of tilt and swing. For this table only, swing and tilt may be used interchangeably.

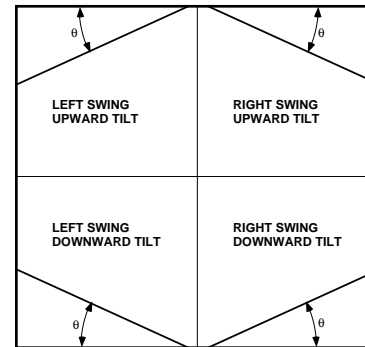
Example: If a lens is tilted by 10° (up or down) and swung by 5° (left or right), the total effective tilt is 11.2°.

TABLE IIb: HINGE LINE TILT FOR COMBINED TILT AND SWING

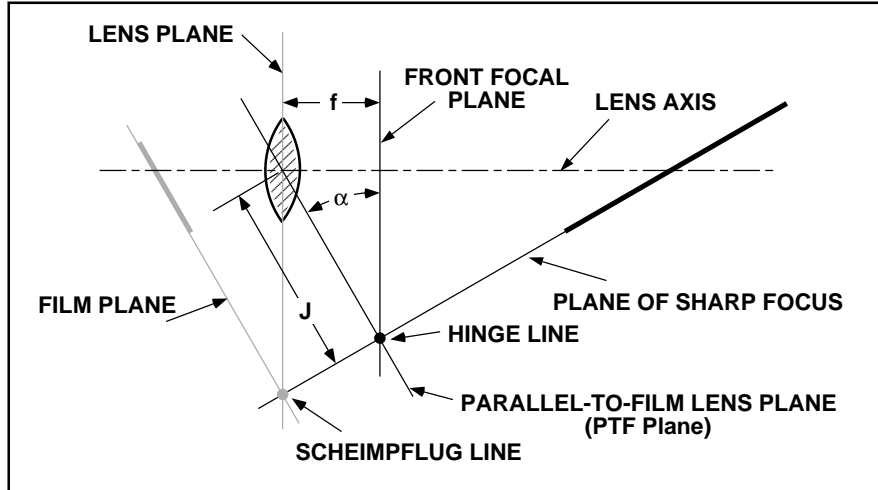
TILT (degrees)	SWING (degrees)																								
	0	0.5	1	1.5	2	2.5	3	4	5	6	7	8	9	10	12	15	20	25	30	35	40	45	50	60	70
0	n/a	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
0.5	0.0	45.0	63.4	71.6	76.0	78.7	80.5	82.9	84.3	85.2	85.9	86.4	86.8	87.1	87.6	88.1	88.5	88.8	89.0	89.1	89.2	89.3	89.3	89.4	89.5
1	0.0	26.6	45.0	56.3	63.4	68.2	71.6	76.0	78.7	80.5	81.8	82.9	83.6	84.3	85.2	86.1	87.1	87.6	88.0	88.3	88.4	88.6	88.7	88.8	88.9
1.5	0.0	18.4	33.7	45.0	53.1	59.0	63.4	69.4	73.3	75.9	77.9	79.3	80.5	81.4	82.8	84.2	85.6	86.5	87.0	87.4	87.7	87.9	88.0	88.3	88.4
2	0.0	14.0	26.6	36.9	45.0	51.3	56.3	63.4	68.2	71.5	74.0	75.9	77.4	78.6	80.5	82.3	84.2	85.3	86.0	86.5	86.9	87.2	87.4	87.7	87.9
2.5	0.0	11.3	21.8	30.9	38.6	45.0	50.2	58.0	63.4	67.3	70.3	72.6	74.4	75.9	78.1	80.4	82.7	84.1	85.0	85.6	86.1	86.5	86.7	87.1	87.3
3	0.0	9.5	18.4	26.5	33.7	39.8	45.0	53.1	59.0	63.4	66.7	69.4	71.5	73.2	75.9	78.6	81.3	82.9	84.0	84.8	85.3	85.8	86.1	86.5	86.8
4	0.0	7.1	14.0	20.5	26.5	32.0	36.8	44.9	51.3	56.2	60.2	63.3	65.9	68.1	71.4	74.9	78.4	80.6	82.0	83.0	83.8	84.4	84.8	85.4	85.7
5	0.0	5.7	11.3	16.7	21.7	26.5	30.9	38.6	44.9	50.1	54.3	57.8	60.8	63.3	67.2	71.3	75.7	78.3	80.1	81.3	82.2	82.9	83.5	84.2	84.7
6	0.0	4.7	9.4	14.0	18.4	22.5	26.5	33.6	39.7	44.8	49.2	52.9	56.1	58.8	63.2	67.9	72.9	76.0	78.1	79.6	80.7	81.5	82.2	83.1	83.6
7	0.0	4.1	8.1	12.0	15.9	19.6	23.1	29.6	35.4	40.4	44.8	48.6	51.9	54.7	59.4	64.6	70.3	73.8	76.2	77.9	79.2	80.1	80.9	81.9	82.6
8	0.0	3.6	7.1	10.6	13.9	17.2	20.4	26.4	31.8	36.6	40.9	44.7	48.1	51.0	55.9	61.5	67.7	71.6	74.3	76.2	77.7	78.8	79.6	80.8	81.5
9	0.0	3.2	6.3	9.4	12.4	15.4	18.3	23.8	28.8	33.4	37.6	41.3	44.6	47.6	52.7	58.5	65.2	69.5	72.4	74.6	76.2	77.4	78.3	79.6	80.4
10	0.0	2.8	5.7	8.4	11.2	13.9	16.5	21.6	26.3	30.7	34.7	38.3	41.6	44.6	49.7	55.7	62.7	67.4	70.6	72.9	74.7	76.0	77.0	78.5	79.4
12	0.0	2.4	4.7	7.0	9.3	11.6	13.8	18.2	22.3	26.2	29.8	33.2	36.4	39.2	44.4	50.6	58.1	63.3	67.0	69.7	71.7	73.3	74.5	76.2	77.3
15	0.0	1.9	3.7	5.6	7.4	9.2	11.1	14.6	18.0	21.3	24.5	27.4	30.3	32.9	37.8	44.0	51.9	57.6	61.8	65.0	67.4	69.2	70.7	72.8	74.1
20	0.0	1.4	2.7	4.1	5.5	6.8	8.2	10.8	13.5	16.0	18.5	20.9	23.3	25.5	29.7	35.4	43.2	49.3	53.9	57.6	60.5	62.8	64.6	67.2	68.8
25	0.0	1.1	2.1	3.2	4.3	5.3	6.4	8.5	10.6	12.6	14.6	16.6	18.5	20.4	24.0	29.0	36.3	42.2	47.0	50.9	54.0	56.6	58.7	61.7	63.6
30	0.0	0.9	1.7	2.6	3.5	4.3	5.2	6.9	8.6	10.3	11.9	13.6	15.2	16.7	19.8	24.1	30.6	36.2	40.9	44.8	48.1	50.8	53.0	56.3	58.4
35	0.0	0.7	1.4	2.1	2.9	3.6	4.3	5.7	7.1	8.5	9.9	11.2	12.6	13.9	16.5	20.3	26.0	31.1	35.5	39.3	42.6	45.3	47.6	51.0	53.3
40	0.0	0.6	1.2	1.8	2.4	3.0	3.6	4.8	5.9	7.1	8.3	9.4	10.6	11.7	13.9	17.1	22.2	26.7	30.8	34.4	37.5	40.1	42.4	45.9	48.2
45	0.0	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	6.9	7.9	8.9	9.9	11.7	14.5	18.9	22.9	26.6	29.8	32.7	35.3	37.5	40.9	43.2
50	0.0	0.4	0.8	1.3	1.7	2.1	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.9	12.3	16.0	19.5	22.8	25.7	28.3	30.7	32.7	36.0	38.3
60	0.0	0.3	0.6	0.9	1.2	1.4	1.7	2.3	2.9	3.5	4.0	4.6	5.2	5.7	6.8	8.5	11.2	13.7	16.1	18.3	20.4	22.2	23.9	26.6	28.5
70	0.0	0.2	0.4	0.5	0.7	0.9	1.1	1.5	1.8	2.2	2.5	2.9	3.3	3.6	4.3	5.4	7.1	8.7	10.3	11.8	13.2	14.4	15.6	17.5	18.9

When both tilt and swing are used, it is also handy to know the transverse orientation of the Plane of Sharp Focus relative to the horizontal plane. The above table tells us the tilt of the Hinge Line (θ) relative to the horizontal. (The Hinge Line is where the Plane of Sharp Focus and the Parallel-to-Film (PTF) Lens Plane intersect.) At right is a diagram showing the orientation of the hinge line in the PTF plane. The camera lens is in the center of the diagram.

Example: If 10° upward lens tilt and 5° left lens swing are used, the Hinge Line is tilted 26.3° from the horizontal, sloping down to the left. For this table, tilt and swing are *not* interchangeable.



$\alpha - \theta$



THE RELATIONSHIPS AMONG J , f and α

The relationship between the lens-to-hinge line distance, J , the lens nominal focal length, f , and the lens tilt, α , are the subject of the next six tables.

Table III tells us the tilt angle, α , required to yield a distance, J , for a variety of common focal lengths. Table IIIa applies when J is measured in meters; Table IIIb applies for J measured in feet. Table III is perhaps the most valuable table in this book. For that reason, it is also reproduced on a separate card at the back of this book.

Table IV tells us the distance, J , that results for a specified tilt angle. Table IVa gives us that distance in meters; Table IVb gives us the distance in feet.

Sometimes we just wish to know the distance J measured in focal lengths. Table Va gives us J/f for J specified in meters; Table Vb gives us J/f for J specified in feet.

Examples:

We wish to know what lens tilt angle to use for a lens-to-hinge line distance of 4 meters with a lens of 115 mm focal length. Looking along the row for the distance 4 meters, and under the column for 115 mm focal length in Table IIIa, we find the required tilt to be 1.65° .

We might also want to know what lens-to-hinge line distance corresponds to a lens tilt of 5° with a 300 mm lens. Consulting Table IVb, looking along the row corresponding to 5° and under the columns for 300 mm, we find the distance to be 11 feet 3.5 inches.

It's easy to divide J by f to find J/f —if you have a calculator. Tables Va and Vb let you do it without one. If $J = 30$ inches and $f = 120$ mm, from table Vb, we find $J/f = 6.35$.

TABLE IIIa: TILT ANGLE, α, FOR DISTANCE, J—in meters

Distance J (in meters)	FOCAL LENGTH (in mm)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.1	32.01°	40.54°	48.59°	64.16°	90.00°	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
0.2	15.37°	18.97°	22.02°	26.74°	30.00°	31.67°	35.10°	36.87°	42.45°	48.59°	64.16°	n/a	n/a	n/a	n/a
0.3	10.18°	12.51°	14.48°	17.46°	19.47°	20.49°	22.54°	23.58°	26.74°	30.00°	36.87°	44.43°	53.13°	90.00°	n/a
0.4	7.61°	9.35°	10.81°	13.00°	14.48°	15.22°	16.71°	17.46°	19.72°	22.02°	26.74°	31.67°	36.87°	48.59°	n/a
0.5	6.08°	7.47°	8.63°	10.37°	11.54°	12.12°	13.30°	13.89°	15.66°	17.46°	21.10°	24.83°	28.69°	36.87°	64.16°
0.75	4.05°	4.97°	5.74°	6.89°	7.66°	8.05°	8.82°	9.21°	10.37°	11.54°	13.89°	16.26°	18.66°	23.58°	36.87°
1	3.04°	3.73°	4.30°	5.16°	5.74°	6.03°	6.60°	6.89°	7.76°	8.63°	10.37°	12.12°	13.89°	17.46°	26.74°
1.5	2.02°	2.48°	2.87°	3.44°	3.82°	4.01°	4.40°	4.59°	5.16°	5.74°	6.89°	8.05°	9.21°	11.54°	17.46°
2	1.52°	1.86°	2.15°	2.58°	2.87°	3.01°	3.30°	3.44°	3.87°	4.30°	5.16°	6.03°	6.89°	8.63°	13.00°
2.5	1.21°	1.49°	1.72°	2.06°	2.29°	2.41°	2.64°	2.75°	3.10°	3.44°	4.13°	4.82°	5.51°	6.89°	10.37°
3	1.01°	1.24°	1.43°	1.72°	1.91°	2.01°	2.20°	2.29°	2.58°	2.87°	3.44°	4.01°	4.59°	5.74°	8.63°
4	0.76°	0.93°	1.07°	1.29°	1.43°	1.50°	1.65°	1.72°	1.93°	2.15°	2.58°	3.01°	3.44°	4.30°	6.46°
5	0.61°	0.74°	0.86°	1.03°	1.15°	1.20°	1.32°	1.38°	1.55°	1.72°	2.06°	2.41°	2.75°	3.44°	5.16°
6	0.51°	0.62°	0.72°	0.86°	0.95°	1.00°	1.10°	1.15°	1.29°	1.43°	1.72°	2.01°	2.29°	2.87°	4.30°
7	0.43°	0.53°	0.61°	0.74°	0.82°	0.86°	0.94°	0.98°	1.11°	1.23°	1.47°	1.72°	1.96°	2.46°	3.69°
8	0.38°	0.47°	0.54°	0.64°	0.72°	0.75°	0.82°	0.86°	0.97°	1.07°	1.29°	1.50°	1.72°	2.15°	3.22°
9	0.34°	0.41°	0.48°	0.57°	0.64°	0.67°	0.73°	0.76°	0.86°	0.95°	1.15°	1.34°	1.53°	1.91°	2.87°
10	0.30°	0.37°	0.43°	0.52°	0.57°	0.60°	0.66°	0.69°	0.77°	0.86°	1.03°	1.20°	1.38°	1.72°	2.58°
12	0.25°	0.31°	0.36°	0.43°	0.48°	0.50°	0.55°	0.57°	0.64°	0.72°	0.86°	1.00°	1.15°	1.43°	2.15°
15	0.20°	0.25°	0.29°	0.34°	0.38°	0.40°	0.44°	0.46°	0.52°	0.57°	0.69°	0.80°	0.92°	1.15°	1.72°
20	0.15°	0.19°	0.21°	0.26°	0.29°	0.30°	0.33°	0.34°	0.39°	0.43°	0.52°	0.60°	0.69°	0.86°	1.29°
25	0.12°	0.15°	0.17°	0.21°	0.23°	0.24°	0.26°	0.28°	0.31°	0.34°	0.41°	0.48°	0.55°	0.69°	1.03°
30	0.10°	0.12°	0.14°	0.17°	0.19°	0.20°	0.22°	0.23°	0.26°	0.29°	0.34°	0.40°	0.46°	0.57°	0.86°
50	0.06°	0.07°	0.09°	0.10°	0.11°	0.12°	0.13°	0.14°	0.15°	0.17°	0.21°	0.24°	0.28°	0.34°	0.52°

TABLE IIIb: TILT ANGLE, α , FOR DISTANCE, J—in feet

Distance J (in feet)	FOCAL LENGTH (in mm)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.25 (3")	44.07°	58.54°	79.82°	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
0.5 (6")	20.35°	25.25°	29.48°	36.20°	41.01°	43.55°	48.99°	51.94°	62.35°	79.82°	n/a	n/a	n/a	n/a	n/a
0.75 (9")	13.41°	16.52°	19.15°	23.18°	25.94°	27.34°	30.20°	31.66°	36.20°	41.01°	51.94°	66.73°	n/a	n/a	n/a
1	10.01°	12.31°	14.24°	17.17°	19.15°	20.15°	22.17°	23.18°	26.29°	29.48°	36.20°	43.55°	51.94°	79.82°	n/a
1.25 (15")	8.00°	9.82°	11.35°	13.66°	15.22°	16.00°	17.57°	18.36°	20.75°	23.18°	28.19°	33.45°	39.04°	51.94°	n/a
1.5 (18")	6.66°	8.17°	9.44°	11.35°	12.63°	13.28°	14.57°	15.22°	17.17°	19.15°	23.18°	27.34°	31.66°	41.01°	79.82°
2	4.99°	6.12°	7.07°	8.49°	9.44°	9.92°	10.87°	11.35°	12.79°	14.24°	17.17°	20.15°	23.18°	29.48°	47.58°
2.5 (30")	3.99°	4.89°	5.65°	6.78°	7.54°	7.92°	8.68°	9.06°	10.20°	11.35°	13.66°	16.00°	18.36°	23.18°	36.20°
3	3.32°	4.08°	4.70°	5.65°	6.28°	6.59°	7.22°	7.54°	8.49°	9.44°	11.35°	13.28°	15.22°	19.15°	29.48°
4	2.49°	3.06°	3.53°	4.23°	4.70°	4.94°	5.41°	5.65°	6.36°	7.07°	8.49°	9.92°	11.35°	14.24°	21.66°
5	1.99°	2.44°	2.82°	3.39°	3.76°	3.95°	4.33°	4.52°	5.08°	5.65°	6.78°	7.92°	9.06°	11.35°	17.17°
6	1.66°	2.04°	2.35°	2.82°	3.13°	3.29°	3.61°	3.76°	4.23°	4.70°	5.65°	6.59°	7.54°	9.44°	14.24°
7	1.42°	1.75°	2.01°	2.42°	2.69°	2.82°	3.09°	3.22°	3.63°	4.03°	4.84°	5.65°	6.46°	8.08°	12.18°
8	1.25°	1.53°	1.76°	2.12°	2.35°	2.47°	2.70°	2.82°	3.17°	3.53°	4.23°	4.94°	5.65°	7.07°	10.63°
9	1.11°	1.36°	1.57°	1.88°	2.09°	2.19°	2.40°	2.51°	2.82°	3.13°	3.76°	4.39°	5.02°	6.28°	9.44°
10	1.00°	1.22°	1.41°	1.69°	1.88°	1.97°	2.16°	2.26°	2.54°	2.82°	3.39°	3.95°	4.52°	5.65°	8.49°
12	0.83°	1.02°	1.17°	1.41°	1.57°	1.65°	1.80°	1.88°	2.12°	2.35°	2.82°	3.29°	3.76°	4.70°	7.07°
15	0.66°	0.81°	0.94°	1.13°	1.25°	1.32°	1.44°	1.50°	1.69°	1.88°	2.26°	2.63°	3.01°	3.76°	5.65°
20	0.50°	0.61°	0.70°	0.85°	0.94°	0.99°	1.08°	1.13°	1.27°	1.41°	1.69°	1.97°	2.26°	2.82°	4.23°
30	0.33°	0.41°	0.47°	0.56°	0.63°	0.66°	0.72°	0.75°	0.85°	0.94°	1.13°	1.32°	1.50°	1.88°	2.82°
50	0.20°	0.24°	0.28°	0.34°	0.38°	0.39°	0.43°	0.45°	0.51°	0.56°	0.68°	0.79°	0.90°	1.13°	1.69°
75	0.13°	0.16°	0.19°	0.23°	0.25°	0.26°	0.29°	0.30°	0.34°	0.38°	0.45°	0.53°	0.60°	0.75°	1.13°
100	0.10°	0.12°	0.14°	0.17°	0.19°	0.20°	0.22°	0.23°	0.25°	0.28°	0.34°	0.39°	0.45°	0.56°	0.85°
200	0.05°	0.06°	0.07°	0.08°	0.09°	0.10°	0.11°	0.11°	0.13°	0.14°	0.17°	0.20°	0.23°	0.28°	0.42°

α for J

TABLE IVa: DISTANCE, J—in meters—FOR TILT ANGLE, α

Tilt Angle (in degrees)	FOCAL LENGTH (in mm)															
	J/f	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
0.5	114.6	6.07 m	7.45 m	8.59 m	10.31 m	11.46 m	12.03 m	13.18 m	13.75 m	15.47 m	17.19 m	20.63 m	24.06 m	27.50 m	34.38 m	51.57 m
1	57.30	3.04 m	3.72 m	4.30 m	5.16 m	5.73 m	6.02 m	6.59 m	6.88 m	7.74 m	8.59 m	10.31 m	12.03 m	13.75 m	17.19 m	25.78 m
1.5	38.20	2.02 m	2.48 m	2.87 m	3.44 m	3.82 m	4.01 m	4.39 m	4.58 m	5.16 m	5.73 m	6.88 m	8.02 m	9.17 m	11.46 m	17.19 m
2	28.65	1.52 m	1.86 m	2.15 m	2.58 m	2.87 m	3.01 m	3.30 m	3.44 m	3.87 m	4.30 m	5.16 m	6.02 m	6.88 m	8.60 m	12.89 m
2.5	22.93	1.22 m	1.49 m	1.72 m	2.06 m	2.29 m	2.41 m	2.64 m	2.75 m	3.09 m	3.44 m	4.13 m	4.81 m	5.50 m	6.88 m	10.32 m
3	19.11	1.01 m	1.24 m	1.43 m	1.72 m	1.91 m	2.01 m	2.20 m	2.29 m	2.58 m	2.87 m	3.44 m	4.01 m	4.59 m	5.73 m	8.60 m
4	14.34	0.76 m	0.93 m	1.08 m	1.29 m	1.43 m	1.51 m	1.65 m	1.72 m	1.94 m	2.15 m	2.58 m	3.01 m	3.44 m	4.30 m	6.45 m
5	11.47	0.61 m	0.75 m	0.86 m	1.03 m	1.15 m	1.20 m	1.32 m	1.38 m	1.55 m	1.72 m	2.07 m	2.41 m	2.75 m	3.44 m	5.16 m
6	9.57	0.51 m	0.62 m	0.72 m	0.86 m	0.96 m	1.00 m	1.10 m	1.15 m	1.29 m	1.44 m	1.72 m	2.01 m	2.30 m	2.87 m	4.31 m
7	8.21	0.43 m	0.53 m	0.62 m	0.74 m	0.82 m	0.86 m	0.94 m	0.98 m	1.11 m	1.23 m	1.48 m	1.72 m	1.97 m	2.46 m	3.69 m
8	7.19	0.38 m	0.47 m	0.54 m	0.65 m	0.72 m	0.75 m	0.83 m	0.86 m	0.97 m	1.08 m	1.29 m	1.51 m	1.72 m	2.16 m	3.23 m
9	6.39	0.34 m	0.42 m	0.48 m	0.58 m	0.64 m	0.67 m	0.74 m	0.77 m	0.86 m	0.96 m	1.15 m	1.34 m	1.53 m	1.92 m	2.88 m
10	5.76	0.31 m	0.37 m	0.43 m	0.52 m	0.58 m	0.60 m	0.66 m	0.69 m	0.78 m	0.86 m	1.04 m	1.21 m	1.38 m	1.73 m	2.59 m
12.5	4.62	0.24 m	0.30 m	0.35 m	0.42 m	0.46 m	0.49 m	0.53 m	0.55 m	0.62 m	0.69 m	0.83 m	0.97 m	1.11 m	1.39 m	2.08 m
15	3.86	0.20 m	0.25 m	0.29 m	0.35 m	0.39 m	0.41 m	0.44 m	0.46 m	0.52 m	0.58 m	0.70 m	0.81 m	0.93 m	1.16 m	1.74 m
20	2.92	0.15 m	0.19 m	0.22 m	0.26 m	0.29 m	0.31 m	0.34 m	0.35 m	0.39 m	0.44 m	0.53 m	0.61 m	0.70 m	0.88 m	1.32 m
25	2.37	0.13 m	0.15 m	0.18 m	0.21 m	0.24 m	0.25 m	0.27 m	0.28 m	0.32 m	0.35 m	0.43 m	0.50 m	0.57 m	0.71 m	1.06 m
30	2.00	0.11 m	0.13 m	0.15 m	0.18 m	0.20 m	0.21 m	0.23 m	0.24 m	0.27 m	0.30 m	0.36 m	0.42 m	0.48 m	0.60 m	0.90 m
35	1.74	0.09 m	0.11 m	0.13 m	0.16 m	0.17 m	0.18 m	0.20 m	0.21 m	0.24 m	0.26 m	0.31 m	0.37 m	0.42 m	0.52 m	0.78 m
40	1.56	0.08 m	0.10 m	0.12 m	0.14 m	0.16 m	0.16 m	0.18 m	0.19 m	0.21 m	0.23 m	0.28 m	0.33 m	0.37 m	0.47 m	0.70 m
45	1.41	0.07 m	0.09 m	0.11 m	0.13 m	0.14 m	0.15 m	0.16 m	0.17 m	0.19 m	0.21 m	0.25 m	0.30 m	0.34 m	0.42 m	0.64 m
50	1.31	0.07 m	0.08 m	0.10 m	0.12 m	0.13 m	0.14 m	0.15 m	0.16 m	0.18 m	0.20 m	0.23 m	0.27 m	0.31 m	0.39 m	0.59 m
60	1.15	0.06 m	0.08 m	0.09 m	0.10 m	0.12 m	0.12 m	0.13 m	0.14 m	0.16 m	0.17 m	0.21 m	0.24 m	0.28 m	0.35 m	0.52 m

TABLE IVb: DISTANCE, J —in feet—FOR TILT ANGLE, α

Tilt Angle (in degrees)	FOCAL LENGTH (in mm)															
	J/f	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
0.5	114.6	19' 11.1"	24' 5.2"	28' 2.4"	33' 10.0"	37' 7.2"	39' 5.7"	43' 2.8"	45' 1.4"	50' 9.1"	56' 4.7"	67' 8.1"	78' 11.4"	90' 2.8"	112' 9.5"	169' 2.2"
1	57.30	9' 11.6"	12' 2.6"	14' 1.2"	16' 11.0"	18' 9.6"	19' 8.9"	21' 7.4"	22' 6.7"	25' 4.5"	28' 2.4"	33' 10.1"	39' 5.7"	45' 1.4"	56' 4.8"	84' 7.1"
1.5	38.20	6' 7.7"	8' 1.8"	9' 4.8"	11' 3.4"	12' 6.4"	13' 1.9"	14' 5.0"	15' 0.5"	16' 11.0"	18' 9.6"	22' 6.7"	26' 3.8"	30' 1.0"	37' 7.2"	56' 4.8"
2	28.65	4' 11.8"	6' 1.3"	7' 0.6"	8' 5.5"	9' 4.8"	9' 10.5"	10' 9.7"	11' 3.4"	12' 8.3"	14' 1.2"	16' 11.1"	19' 8.9"	22' 6.7"	28' 2.4"	42' 3.6"
2.5	22.93	3' 11.8"	4' 10.7"	5' 7.7"	6' 9.2"	7' 6.3"	7' 10.8"	8' 7.8"	9' 0.3"	10' 1.8"	11' 3.4"	13' 6.5"	15' 9.5"	18' 0.6"	22' 6.8"	33' 10.2"
3	19.11	3' 3.9"	4' 0.9"	4' 8.4"	5' 7.7"	6' 3.2"	6' 7.0"	7' 2.5"	7' 6.3"	8' 5.6"	9' 4.8"	11' 3.4"	13' 2.0"	15' 0.5"	18' 9.7"	28' 2.5"
4	14.34	2' 5.9"	3' 0.7"	3' 6.3"	4' 2.8"	4' 8.4"	4' 11.3"	5' 4.9"	5' 7.7"	6' 4.2"	7' 0.7"	8' 5.6"	9' 10.5"	11' 3.5"	14' 1.3"	21' 2.0"
5	11.47	1' 11.9"	2' 5.4"	2' 9.9"	3' 4.7"	3' 9.2"	3' 11.4"	4' 3.9"	4' 6.2"	5' 1.0"	5' 7.8"	6' 9.3"	7' 10.9"	9' 0.4"	11' 3.5"	16' 11.3"
6	9.57	1' 8.0"	2' 0.5"	2' 4.2"	2' 9.9"	3' 1.7"	3' 3.5"	3' 7.3"	3' 9.2"	4' 2.8"	4' 8.5"	5' 7.8"	6' 7.1"	7' 6.4"	9' 5.0"	14' 1.5"
7	8.21	1' 5.1"	1' 9.0"	2' 0.2"	2' 5.1"	2' 8.3"	2' 9.9"	3' 1.2"	3' 2.8"	3' 7.6"	4' 0.5"	4' 10.1"	5' 7.8"	6' 5.5"	8' 0.9"	12' 1.4"
8	7.19	1' 3.0"	1' 6.4"	1' 9.2"	2' 1.5"	2' 4.3"	2' 5.7"	2' 8.5"	2' 9.9"	3' 2.2"	3' 6.4"	4' 2.9"	4' 11.4"	5' 7.9"	7' 0.9"	10' 7.3"
9	6.39	1' 1.3"	1' 4.4"	1' 6.9"	1' 10.7"	2' 1.2"	2' 2.4"	2' 4.9"	2' 6.2"	2' 10.0"	3' 1.8"	3' 9.3"	4' 4.9"	5' 0.4"	6' 3.5"	9' 5.3"
10	5.76	1' 0.0"	1' 2.7"	1' 5.0"	1' 8.4"	1' 10.7"	1' 11.8"	2' 2.1"	2' 3.2"	2' 6.6"	2' 10.0"	3' 4.8"	3' 11.6"	4' 6.4"	5' 8.0"	8' 6.0"
12.5	4.62	0' 9.6"	0' 11.8"	1' 1.6"	1' 4.4"	1' 6.2"	1' 7.1"	1' 8.9"	1' 9.8"	2' 0.6"	2' 3.3"	2' 8.7"	3' 2.2"	3' 7.7"	4' 6.6"	6' 9.9"
15	3.86	0' 8.1"	0' 9.9"	0' 11.4"	1' 1.7"	1' 3.2"	1' 4.0"	1' 5.5"	1' 6.3"	1' 8.5"	1' 10.8"	2' 3.4"	2' 7.9"	3' 0.5"	3' 9.6"	5' 8.5"
20	2.92	0' 6.1"	0' 7.5"	0' 8.6"	0' 10.4"	0' 11.5"	1' 0.1"	1' 1.2"	1' 1.8"	1' 3.5"	1' 5.3"	1' 8.7"	2' 0.2"	2' 3.6"	2' 10.5"	4' 3.8"
25	2.37	0' 4.9"	0' 6.1"	0' 7.0"	0' 8.4"	0' 9.3"	0' 9.8"	0' 10.7"	0' 11.2"	1' 0.6"	1' 2.0"	1' 4.8"	1' 7.6"	1' 10.4"	2' 3.9"	3' 5.9"
30	2.00	0' 4.2"	0' 5.1"	0' 5.9"	0' 7.1"	0' 7.9"	0' 8.3"	0' 9.1"	0' 9.4"	0' 10.6"	0' 11.8"	1' 2.2"	1' 4.5"	1' 6.9"	1' 11.6"	2' 11.4"
35	1.74	0' 3.6"	0' 4.5"	0' 5.1"	0' 6.2"	0' 6.9"	0' 7.2"	0' 7.9"	0' 8.2"	0' 9.3"	0' 10.3"	1' 0.4"	1' 2.4"	1' 4.5"	1' 8.6"	2' 6.9"
40	1.56	0' 3.2"	0' 4.0"	0' 4.6"	0' 5.5"	0' 6.1"	0' 6.4"	0' 7.0"	0' 7.3"	0' 8.3"	0' 9.2"	0' 11.0"	1' 0.9"	1' 2.7"	1' 6.4"	2' 3.6"
45	1.41	0' 3.0"	0' 3.6"	0' 4.2"	0' 5.0"	0' 5.6"	0' 5.8"	0' 6.4"	0' 6.7"	0' 7.5"	0' 8.4"	0' 10.0"	0' 11.7"	1' 1.4"	1' 4.7"	2' 1.1"
50	1.31	0' 2.7"	0' 3.3"	0' 3.9"	0' 4.6"	0' 5.1"	0' 5.4"	0' 5.9"	0' 6.2"	0' 6.9"	0' 7.7"	0' 9.3"	0' 10.8"	1' 0.3"	1' 3.4"	1' 11.1"
60	1.15	0' 2.4"	0' 3.0"	0' 3.4"	0' 4.1"	0' 4.5"	0' 4.8"	0' 5.2"	0' 5.5"	0' 6.1"	0' 6.8"	0' 8.2"	0' 9.5"	0' 10.9"	1' 1.6"	1' 8.5"

J for α

TABLE Va: J/f—J in meters

Distance J (in meters)	FOCAL LENGTH (in mm)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.1	1.89	1.54	1.33	1.11	1.00	0.95	0.87	0.83	0.74	0.67	0.56	0.48	0.42	0.33	0.22
0.2	3.77	3.08	2.67	2.22	2.00	1.90	1.74	1.67	1.48	1.33	1.11	0.95	0.83	0.67	0.44
0.3	5.66	4.62	4.00	3.33	3.00	2.86	2.61	2.50	2.22	2.00	1.67	1.43	1.25	1.00	0.67
0.4	7.55	6.15	5.33	4.44	4.00	3.81	3.48	3.33	2.96	2.67	2.22	1.90	1.67	1.33	0.89
0.5	9.43	7.69	6.67	5.56	5.00	4.76	4.35	4.17	3.70	3.33	2.78	2.38	2.08	1.67	1.11
0.75	14.2	11.5	10.0	8.33	7.50	7.14	6.52	6.25	5.56	5.00	4.17	3.57	3.13	2.50	1.67
1	18.9	15.4	13.3	11.1	10.0	9.52	8.70	8.33	7.41	6.67	5.56	4.76	4.17	3.33	2.22
1.5	28.3	23.1	20.0	16.7	15.0	14.3	13.0	12.5	11.1	10.0	8.33	7.14	6.25	5.00	3.33
2	37.7	30.8	26.7	22.2	20.0	19.0	17.4	16.7	14.8	13.3	11.1	9.52	8.33	6.67	4.44
2.5	47.2	38.5	33.3	27.8	25.0	23.8	21.7	20.8	18.5	16.7	13.9	11.9	10.4	8.33	5.56
3	56.6	46.2	40.0	33.3	30.0	28.6	26.1	25.0	22.2	20.0	16.7	14.3	12.5	10.0	6.67
4	75.5	61.5	53.3	44.4	40.0	38.1	34.8	33.3	29.6	26.7	22.2	19.0	16.7	13.3	8.89
5	94.3	76.9	66.7	55.6	50.0	47.6	43.5	41.7	37.0	33.3	27.8	23.8	20.8	16.7	11.1
6	113.	92.3	80.0	66.7	60.0	57.1	52.2	50.0	44.4	40.0	33.3	28.6	25.0	20.0	13.3
7	132.	108.	93.3	77.8	70.0	66.7	60.9	58.3	51.9	46.7	38.9	33.3	29.2	23.3	15.6
8	151.	123.	107.	88.9	80.0	76.2	69.6	66.7	59.3	53.3	44.4	38.1	33.3	26.7	17.8
9	170.	138.	120.	100.	90.0	85.7	78.3	75.0	66.7	60.0	50.0	42.9	37.5	30.0	20.0
10	189.	154.	133.	111.	100.	95.2	87.0	83.3	74.1	66.7	55.6	47.6	41.7	33.3	22.2
12	226.	185.	160.	133.	120.	114.	104.	100.	88.9	80.0	66.7	57.1	50.0	40.0	26.7
15	283.	231.	200.	167.	150.	143.	130.	125.	111.	100.	83.3	71.4	62.5	50.0	33.3
20	377.	308.	267.	222.	200.	190.	174.	167.	148.	133.	111.	95.2	83.3	66.7	44.4
25	472.	385.	333.	278.	250.	238.	217.	208.	185.	167.	139.	119.	104.	83.3	55.6
30	566.	462.	400.	333.	300.	286.	261.	250.	222.	200.	167.	143.	125.	100.	66.7
50	943.	769.	667.	556.	500.	476.	435.	417.	370.	333.	278.	238.	208.	167.	111.

TABLE Vb: J/f—J in feet

Distance J (in feet)	FOCAL LENGTH (in mm)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.25 (3")	1.44	1.17	1.02	0.85	0.76	0.73	0.66	0.64	0.56	0.51	0.42	0.36	0.32	0.25	0.17
0.5 (6")	2.88	2.34	2.03	1.69	1.52	1.45	1.33	1.27	1.13	1.02	0.85	0.73	0.64	0.51	0.34
0.75 (9")	4.31	3.52	3.05	2.54	2.29	2.18	1.99	1.91	1.69	1.52	1.27	1.09	0.95	0.76	0.51
1	5.75	4.69	4.06	3.39	3.05	2.90	2.65	2.54	2.26	2.03	1.69	1.45	1.27	1.02	0.68
1.25 (15")	7.19	5.86	5.08	4.23	3.81	3.63	3.31	3.18	2.82	2.54	2.12	1.81	1.59	1.27	0.85
1.5 (18")	8.63	7.03	6.10	5.08	4.57	4.35	3.98	3.81	3.39	3.05	2.54	2.18	1.91	1.52	1.02
2	11.5	9.38	8.13	6.77	6.10	5.81	5.30	5.08	4.52	4.06	3.39	2.90	2.54	2.03	1.35
2.5 (30")	14.4	11.7	10.2	8.47	7.62	7.26	6.63	6.35	5.64	5.08	4.23	3.63	3.18	2.54	1.69
3	17.3	14.1	12.2	10.2	9.14	8.71	7.95	7.62	6.77	6.10	5.08	4.35	3.81	3.05	2.03
4	23.0	18.8	16.3	13.5	12.2	11.6	10.6	10.2	9.03	8.13	6.77	5.81	5.08	4.06	2.71
5	28.8	23.4	20.3	16.9	15.2	14.5	13.3	12.7	11.3	10.2	8.47	7.26	6.35	5.08	3.39
6	34.5	28.1	24.4	20.3	18.3	17.4	15.9	15.2	13.5	12.2	10.2	8.71	7.62	6.10	4.06
7	40.3	32.8	28.4	23.7	21.3	20.3	18.6	17.8	15.8	14.2	11.9	10.2	8.89	7.11	4.74
8	46.0	37.5	32.5	27.1	24.4	23.2	21.2	20.3	18.1	16.3	13.5	11.6	10.2	8.13	5.42
9	51.8	42.2	36.6	30.5	27.4	26.1	23.9	22.9	20.3	18.3	15.2	13.1	11.4	9.14	6.10
10	57.5	46.9	40.6	33.9	30.5	29.0	26.5	25.4	22.6	20.3	16.9	14.5	12.7	10.2	6.77
12	69.0	56.3	48.8	40.6	36.6	34.8	31.8	30.5	27.1	24.4	20.3	17.4	15.2	12.2	8.13
15	86.3	70.3	61.0	50.8	45.7	43.5	39.8	38.1	33.9	30.5	25.4	21.8	19.1	15.2	10.2
20	115.	93.8	81.3	67.7	61.0	58.1	53.0	50.8	45.2	40.6	33.9	29.0	25.4	20.3	13.5
30	173.	141.	122.	102.	91.4	87.1	79.5	76.2	67.7	61.0	50.8	43.5	38.1	30.5	20.3
50	288.	234.	203.	169.	152.	145.	133.	127.	113.	102.	84.7	72.6	63.5	50.8	33.9
75	431.	352.	305.	254.	229.	218.	199.	191.	169.	152.	127.	109.	95.3	76.2	50.8
100	575.	469.	406.	339.	305.	290.	265.	254.	226.	203.	169.	145.	127.	102.	67.7
200	1150.	938.	813.	677.	610.	581.	530.	508.	452.	406.	339.	290.	254.	203.	135.

J/f

BACK FOCUS DISTANCE (A/f) for given Φ and J/f or α

The amount of back focus is usually determined simply by adjusting the back position while observing the ground glass. We can also calculate the lens-to-film plane distance, A , however. Table VI tells you the value of A divided by the focal length, f , for the same values of J/f , α and Φ as are used in the depth of field tables.

Figures 63 and 64 which follow the table show in graph form the relationships between α and Φ for various values of A/f . The two figures show the same data, but Figure 64 expands the scale, allowing better resolution at small values of the lens tilt α .

It is interesting to note that for normal cameras, a lens closer to the film than one focal length guarantees an out-of-focus image. But as soon as lens tilt is introduced, the lens-to-film plane distance can in principle have any positive value. Lens-to-film plane distances less than one focal length are denoted by values of A/f that are less than 1.

Example:

In the example discussed in Chapter 8, I used a 241 mm lens, tilted 6° ($J/f = 10$) and a Φ of 80°). What was the lens-to-film plane distance? From Table VI, we look up $J/f = 10$ and $\Phi = 80^\circ$ to find 1.0232 as the value of A/f . This means the lens-to-film plane distance was 1.0232×241 mm. That is, 246.59 mm: a backwards extension from the normal infinity focus position of 5.59 mm.

TABLE VI: A/f —for α and Φ

LENS TILT		PLANE OF SHARP FOCUS TILT (DEGREES)								
J/f	α	1	2	5	10	20	30	40	50	60
10000	0.006	1.0058	1.0029	1.0011	1.0006	1.0003	1.0002	1.0001	1.0001	1.0001
1000	0.057	1.0608	1.0295	1.0116	1.0057	1.0028	1.0017	1.0012	1.0008	1.0006
200	0.29	1.4015	1.1671	1.0606	1.0292	1.0139	1.0087	1.0060	1.0042	1.0029
100	0.57	2.3416	1.4014	1.1291	1.0602	1.0283	1.0177	1.0121	1.0085	1.0059
50	1.1	n/a	2.3415	1.2967	1.1282	1.0584	1.0361	1.0246	1.0173	1.0119
30	1.9	n/a	22.2705	1.6170	1.2340	1.1015	1.0619	1.0420	1.0294	1.0202
20	2.9	n/a	n/a	2.3406	1.3982	1.1609	1.0963	1.0648	1.0452	1.0311
15	3.8	n/a	n/a	4.2414	1.6137	1.2276	1.1334	1.0889	1.0618	1.0424
10	5.7	n/a	n/a	n/a	2.3372	1.3884	1.2169	1.1418	1.0976	1.0669
7	8.2	n/a	n/a	n/a	5.5692	1.6744	1.3472	1.2203	1.1496	1.1022
5	11.5	n/a	n/a	n/a	n/a	2.3240	1.5788	1.3487	1.2316	1.1570
4	14.5	n/a	n/a	n/a	n/a	3.5540	1.8683	1.4919	1.3184	1.2137
3	19.5	n/a	n/a	n/a	n/a	37.0600	2.7363	1.8330	1.5080	1.3327
2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	3.7017	2.2398	1.7321
1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5.3776	2.7743
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT		PLANE OF SHARP FOCUS TILT (DEGREES)								
J/f	α	70	80	90	100	110	120	130	140	150
10000	0.006	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9999	0.9999	0.9998
1000	0.057	1.0004	1.0002	1.0000	0.9998	0.9996	0.9994	0.9992	0.9988	0.9983
200	0.29	1.0018	1.0009	1.0000	0.9991	0.9982	0.9971	0.9958	0.9941	0.9914
100	0.57	1.0037	1.0018	1.0001	0.9983	0.9964	0.9943	0.9917	0.9883	0.9830
50	1.1	1.0075	1.0037	1.0002	0.9967	0.9930	0.9888	0.9837	0.9769	0.9667
30	1.9	1.0129	1.0065	1.0006	0.9947	0.9886	0.9817	0.9733	0.9623	0.9459
20	2.9	1.0198	1.0102	1.0013	0.9925	0.9833	0.9731	0.9609	0.9449	0.9214
15	3.8	1.0272	1.0142	1.0022	0.9906	0.9784	0.9650	0.9490	0.9283	0.8983
10	5.7	1.0432	1.0232	1.0050	0.9875	0.9696	0.9499	0.9269	0.8975	0.8560
7	8.2	1.0664	1.0367	1.0104	0.9853	0.9599	0.9326	0.9012	0.8621	0.8083
5	11.5	1.1025	1.0587	1.0206	0.9852	0.9500	0.9130	0.8714	0.8209	0.7540
4	14.5	1.1399	1.0821	1.0328	0.9878	0.9441	0.8988	0.8489	0.7898	0.7136
3	19.5	1.2173	1.1312	1.0607	0.9984	0.9397	0.8809	0.8180	0.7462	0.6578
2	30.0	1.4619	1.2856	1.1547	1.0480	0.9542	0.8660	0.7779	0.6840	0.5774
1.5	41.8	1.9892	1.5929	1.3416	1.1589	1.0121	0.8848	0.7664	0.6494	0.5263
1	90.0	n/a	n/a	n/a	5.6713	2.7475	1.7321	1.1918	0.8391	0.5774

A/f

Figure 63: Plane of Sharp Focus Tilt (Φ) for lens tilt (α) and A/f

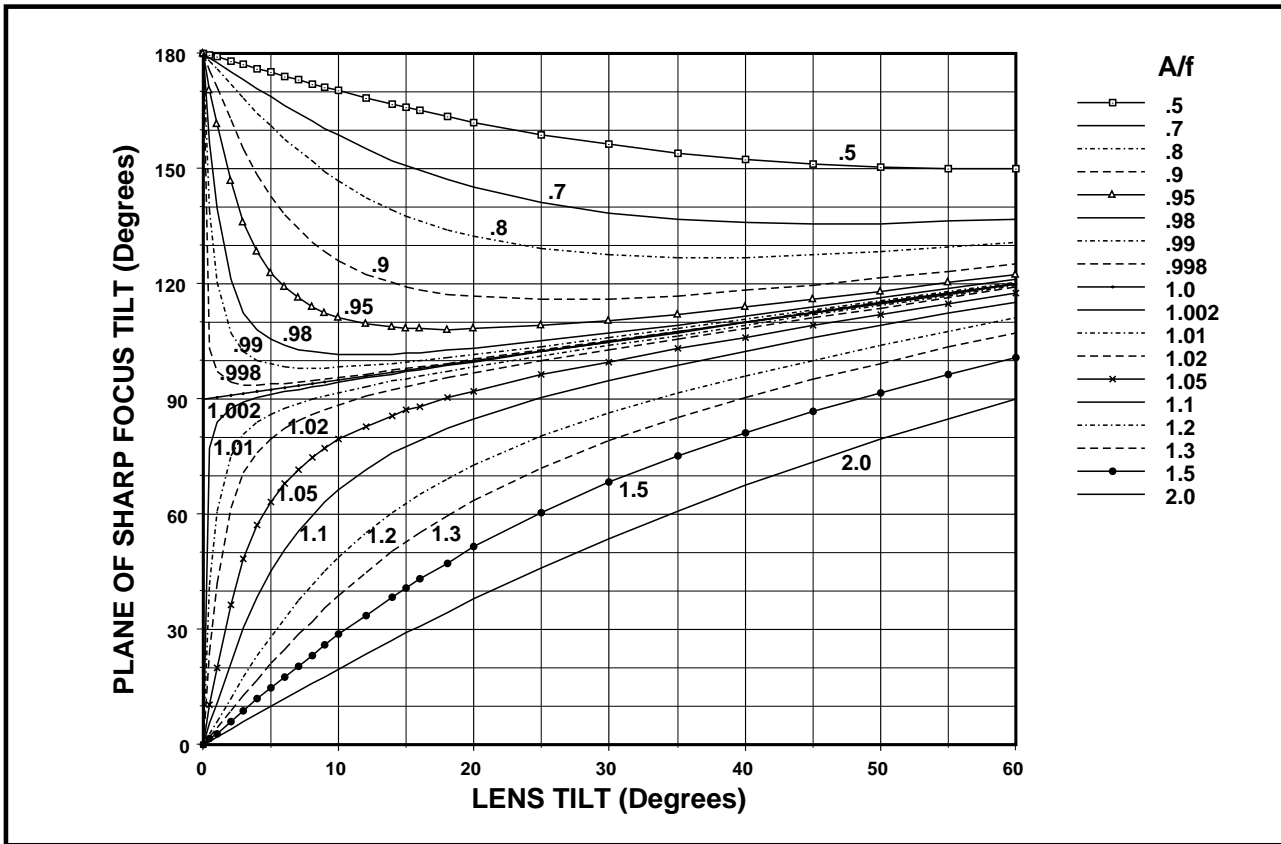
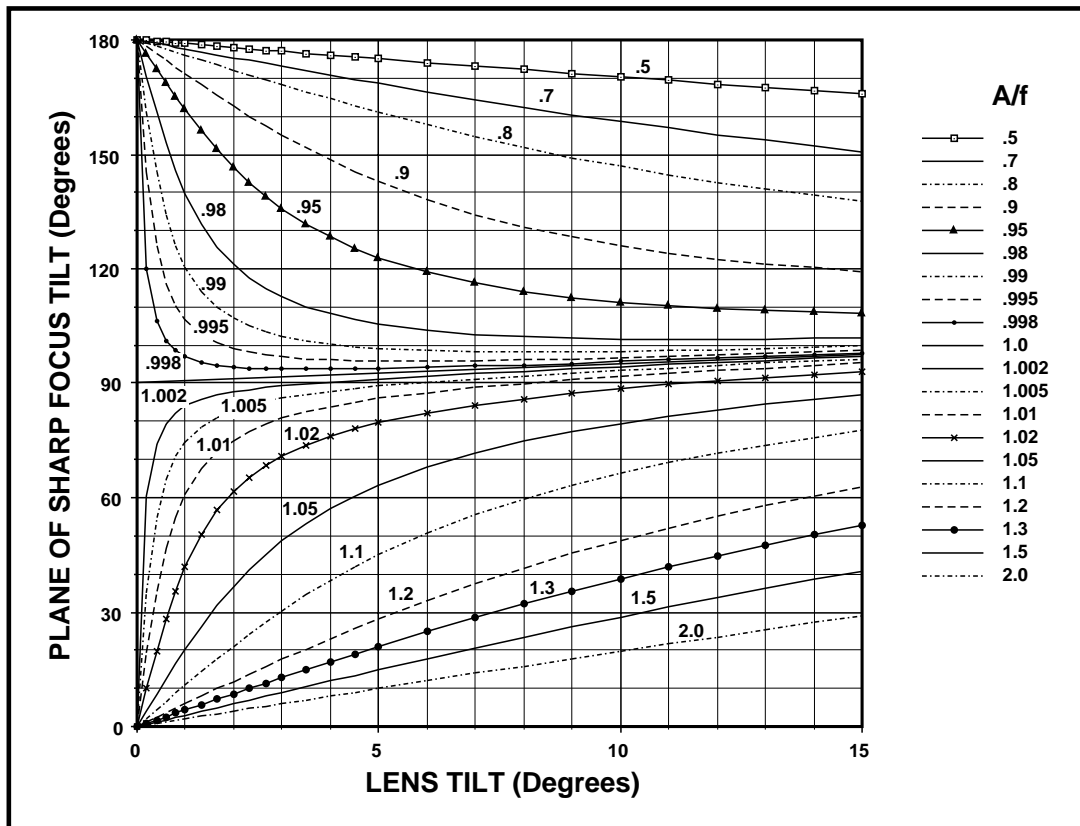
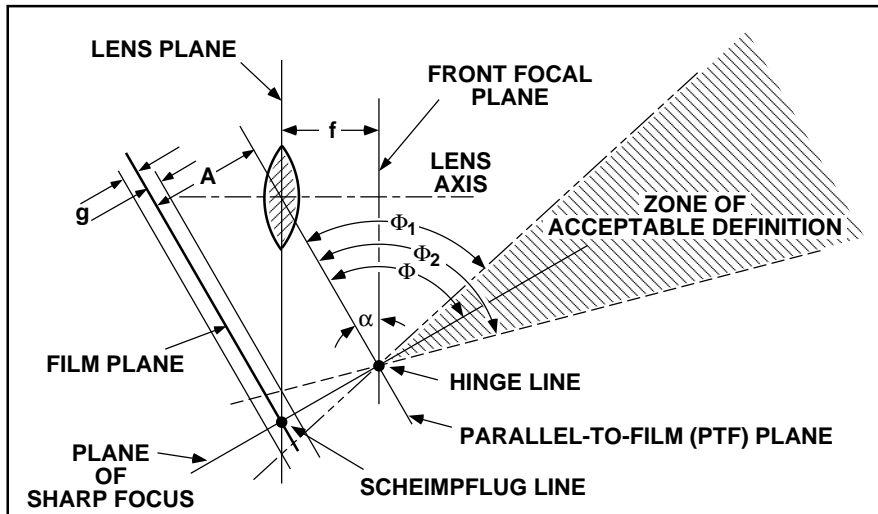


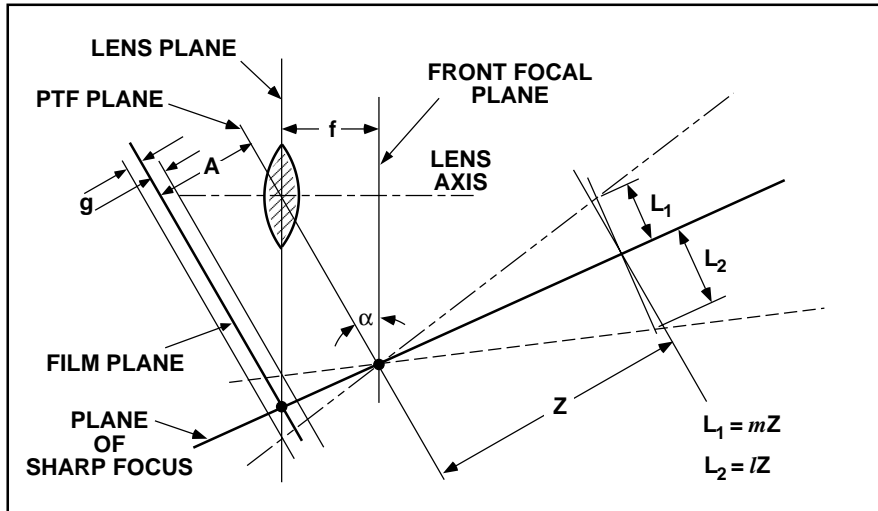
Figure 64: Plane of Sharp Focus Tilt (Φ) for lens tilt (α) and A/f



A/f



For an allowable depth of focus $\pm g$, the depth of field extends from Φ_1 to Φ_2 : the shaded area above.



For an allowable depth of focus $\pm g$, the depth of field can also be described in a direction perpendicular to the Plane of Sharp Focus. In this case we use the symbol L , and expressed depth of field as a fraction of the distance, Z . Z is measured from the PTF plane in a direction perpendicular to it (which is also perpendicular to the lens plane).

DEPTH OF FIELD

The tables that follow describe depth of field in two ways. The tables on the even numbered pages indicate depth of field by angle as described in the top diagram at left. The tables on odd numbered pages give depth of field as a fraction of the distance, **Z**, from the lens to the subject, as described in the diagram at lower left.

The f-number (for which I use the symbol **N**) shown on each table is the one applying when one uses a circle of confusion diameter of one-fifteen-hundredth (1/1500) of the lens focal length. Other combinations of f-number and circle of confusion diameter which can be used are listed at the top left corner of each table. Each table applies for lenses of all focal lengths, but note that the amount of lens tilt required to achieve a given Φ and **J** will depend upon the focal length.

The various symbols are defined briefly as follows. **J** is the distance from the lens to the hinge line, measured along the PTF plane. α , is the tilt angle, of the lens plane relative to the film plane. Φ is the tilt of the plane of sharp focus relative to the film plane. **f** is, of course, the lens focal length. **Z** is the distance from the PTF plane to the subject, measured in a direction perpendicular to the PTF plane. **L** is depth of field measured in a direction perpendicular to the plane of sharp focus.

A space is provided for your notes at the bottom left of each table.

Examples:

See Chapter 8.

TABLE VIIa: DEPTH OF FIELD FOR f/2.8 — by angle

By Angle		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
f-number = 2.8 a/f = 1/1500		LENS TILT		1	2	5	10	20	30	40	50	60
		J/f	α									
Other Combinations:		10000	0.006	0.8° to 1.5°	1.2° to 5.7°	1.9° to 172.1°	2.4° to 175.6°	2.7° to 176.4°	2.8° to 176.6°	2.9° to 176.7°	2.9° to 176.8°	3.0° to 176.8°
		1000	0.057	1.0° to 1.0°	1.9° to 2.1°	4.3° to 5.9°	7.6° to 14.7°	12.3° to 48.4°	15.6° to 97.5°	18.1° to 124.0°	20.3° to 135.8°	22.3° to 142.2°
		200	0.29	1.0° to 1.0°	2.0° to 2.0°	4.9° to 5.1°	9.4° to 10.6°	17.8° to 22.8°	25.5° to 36.2°	32.7° to 50.6°	39.6° to 64.9°	46.5° to 78.4°
		100	0.57	1.0° to 1.0°	2.0° to 2.0°	4.9° to 5.1°	9.7° to 10.3°	18.9° to 21.3°	27.6° to 32.8°	36.1° to 44.7°	44.4° to 56.8°	52.7° to 68.6°
1.0	1/500	50	1.1	n/a	2.0° to 2.0°	5.0° to 5.0°	9.9° to 10.1°	19.5° to 20.6°	28.8° to 31.3°	38.0° to 42.2°	47.1° to 53.2°	56.2° to 64.1°
1.4	1/750	30	1.9	n/a	2.0° to 2.0°	5.0° to 5.0°	9.9° to 10.1°	19.7° to 20.3°	29.3° to 30.7°	38.8° to 41.3°	48.3° to 51.8°	57.7° to 62.4°
2.0	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	10.0° to 10.0°	19.8° to 20.2°	29.6° to 30.5°	39.2° to 40.8°	48.9° to 51.2°	58.5° to 61.5°
2.8	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	10.0° to 10.0°	19.9° to 20.1°	29.7° to 30.3°	39.4° to 40.6°	49.2° to 50.8°	58.9° to 61.1°
4.0	1/2000	10	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.9° to 20.1°	29.8° to 30.2°	39.7° to 40.3°	49.5° to 50.5°	59.3° to 60.7°
5.6	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	20.0° to 20.0°	29.9° to 30.1°	39.8° to 40.2°	49.7° to 50.3°	59.5° to 60.5°
7.9	1/4000	5	11.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.9° to 40.1°	49.8° to 50.2°	59.7° to 60.3°
11	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	39.9° to 40.1°	49.9° to 50.1°	59.8° to 60.2°
16	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	40.0° to 40.0°	49.9° to 50.1°	59.9° to 60.1°
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	40.0° to 40.0°	50.0° to 50.0°	59.9° to 60.1°
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	60.0° to 60.0°
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

By Angle		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
f-number = 2.8 a/f = 1/1500		LENS TILT		70	80	90	100	110	120	130	140	150
		J/f	α									
Other Combinations:		10000	0.006	3.0° to 176.9°	3.0° to 176.9°	3.1° to 176.9°	3.1° to 177.0°	3.1° to 177.0°	3.2° to 177.0°	3.2° to 177.1°	3.3° to 177.1°	3.4° to 177.2°
		1000	0.057	24.2° to 146.4°	26.1° to 149.4°	28.2° to 151.9°	30.7° to 154.0°	33.7° to 155.9°	37.8° to 157.8°	44.2° to 159.8°	55.9° to 161.9°	82.2° to 164.5°
		200	0.29	53.7° to 90.5°	61.3° to 101.1°	69.6° to 110.5°	78.9° to 118.9°	89.4° to 126.5°	101.5° to 133.6°	114.9° to 140.6°	129.2° to 147.5°	143.5° to 154.7°
		100	0.57	61.2° to 79.9°	70.1° to 90.6°	79.4° to 100.6°	89.4° to 110.0°	100.0° to 118.9°	111.3° to 127.5°	123.0° to 135.8°	135.0° to 144.1°	147.0° to 152.6°
50	1.1	50	1.1	65.5° to 74.8°	75.0° to 85.2°	84.7° to 95.3°	94.7° to 105.1°	105.1° to 114.6°	115.7° to 123.9°	126.6° to 133.1°	137.6° to 142.2°	148.5° to 151.4°
30	1.9	30	1.9	67.3° to 72.8°	77.0° to 83.1°	86.8° to 93.2°	96.8° to 103.1°	107.1° to 112.8°	117.4° to 122.4°	128.0° to 131.9°	138.5° to 141.4°	149.1° to 150.9°
20	2.9	20	2.9	68.2° to 71.8°	78.0° to 82.0°	87.9° to 92.1°	97.9° to 102.1°	108.0° to 111.9°	118.3° to 121.7°	128.6° to 131.3°	139.0° to 141.0°	149.4° to 150.6°
15	3.8	15	3.8	68.7° to 71.4°	78.5° to 81.5°	88.4° to 91.6°	98.4° to 101.6°	108.5° to 111.5°	118.7° to 121.3°	128.9° to 131.0°	139.2° to 140.8°	149.5° to 150.5°
10	5.7	10	5.7	69.1° to 70.9°	79.0° to 81.0°	88.9° to 91.1°	98.9° to 101.1°	109.0° to 111.0°	119.1° to 120.9°	129.3° to 130.7°	139.4° to 140.5°	149.6° to 150.4°
7	8.2	7	8.2	69.4° to 70.6°	79.3° to 80.7°	89.3° to 90.7°	99.3° to 100.7°	109.3° to 110.7°	119.4° to 120.6°	129.5° to 130.5°	139.6° to 140.4°	149.7° to 150.3°
5	11.5	5	11.5	69.6° to 70.4°	79.5° to 80.5°	89.5° to 90.5°	99.5° to 100.5°	109.5° to 110.5°	119.5° to 120.5°	129.6° to 130.4°	139.7° to 140.3°	149.8° to 150.2°
4	14.5	4	14.5	69.7° to 70.3°	79.6° to 80.4°	89.6° to 90.4°	99.6° to 100.4°	109.6° to 110.4°	119.6° to 120.4°	129.7° to 130.3°	139.7° to 140.3°	149.8° to 150.2°
3	19.5	3	19.5	69.8° to 70.2°	79.8° to 80.2°	89.7° to 90.3°	99.7° to 100.3°	109.7° to 110.3°	119.7° to 120.3°	129.7° to 130.3°	139.8° to 140.2°	149.8° to 150.2°
2	30.0	2	30.0	69.9° to 70.1°	79.9° to 80.1°	89.8° to 90.2°	99.8° to 100.2°	109.8° to 110.2°	119.8° to 120.2°	129.8° to 130.2°	139.8° to 140.2°	149.8° to 150.2°
1.5	41.8	1.5	41.8	70.0° to 70.0°	79.9° to 80.1°	89.9° to 90.1°	99.9° to 100.1°	109.9° to 110.1°	119.8° to 120.2°	129.8° to 130.2°	139.8° to 140.2°	149.9° to 150.1°
1	90.0	1	90.0	n/a	n/a	n/a	100.0° to 100.0°	110.0° to 110.0°	120.0° to 120.0°	130.0° to 130.0°	139.9° to 140.1°	149.9° to 150.1°

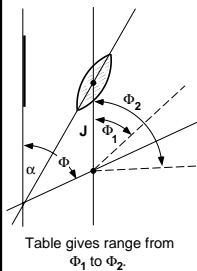


TABLE VIIb: DEPTH OF FIELD FOR f/2.8 — by depth of field fraction

Fractions f-number = 2.8 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
Other combinations: f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	0.243	0.476	0.393	1.85	0.62	Inf.	0.77	Inf.	0.91	Inf.	1.03	Inf.	1.18	Inf.	1.40	Inf.
		1000	0.057	0.028	0.030	0.058	0.066	0.137	0.189	0.243	0.470	0.397	1.58	0.51	4.83	0.62	14.75	0.74	17.73	0.89	8.46
		200	0.29	0.003	0.003	0.009	0.010	0.028	0.030	0.058	0.065	0.111	0.141	0.158	0.219	0.200	0.290	0.239	0.348	0.276	0.384
		100	0.57	0.001	0.001	0.003	0.003	0.013	0.013	0.028	0.030	0.057	0.064	0.083	0.098	0.107	0.129	0.129	0.155	0.148	0.174
1.0	1/500	50	1.1	n/a	n/a	0.001	0.001	0.005	0.005	0.013	0.013	0.028	0.029	0.042	0.045	0.055	0.060	0.066	0.072	0.076	0.082
1.4	1/750	30	1.9	n/a	n/a	0.000	0.000	0.002	0.002	0.006	0.006	0.016	0.016	0.024	0.025	0.032	0.034	0.039	0.042	0.045	0.048
2.0	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.001	0.001	0.003	0.003	0.009	0.010	0.015	0.016	0.021	0.022	0.026	0.027	0.030	0.031
2.8	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.006	0.006	0.011	0.011	0.015	0.015	0.019	0.019	0.022	0.023
4.0	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.003	0.003	0.006	0.006	0.009	0.009	0.012	0.012	0.014	0.014
5.6	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.004	0.004	0.006	0.006	0.008	0.008	0.009	0.009
7.9	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.002	0.002	0.003	0.003	0.005	0.005	0.006	0.006
11	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.004
16	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.001	0.001
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (φ - DEGREES)																	
		70		80		90		100		110		120		130		140		150	
J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
10000	0.006	2.51	Inf.	4.38	Inf.	18.63	18.70	Inf.	4.39	Inf.	2.51	Inf.	1.78	Inf.	1.40	Inf.	1.18	Inf.	1.03
1000	0.057	1.09	4.40	1.39	2.71	1.86	1.87	2.69	1.40	4.37	1.10	8.40	0.90	17.65	0.75	14.94	0.63	4.91	0.52
200	0.29	0.312	0.398	0.344	0.393	0.373	0.374	0.393	0.347	0.399	0.315	0.387	0.280	0.353	0.244	0.298	0.205	0.227	0.163
100	0.57	0.164	0.186	0.177	0.190	0.186	0.187	0.190	0.179	0.188	0.167	0.178	0.151	0.160	0.133	0.135	0.112	0.105	0.089
50	1.1	0.084	0.089	0.090	0.093	0.093	0.093	0.094	0.091	0.092	0.086	0.086	0.080	0.077	0.071	0.066	0.060	0.052	0.048
30	1.9	0.050	0.052	0.054	0.055	0.056	0.056	0.056	0.055	0.055	0.053	0.052	0.049	0.047	0.044	0.040	0.038	0.032	0.031
20	2.9	0.033	0.034	0.036	0.036	0.037	0.037	0.037	0.037	0.037	0.036	0.035	0.034	0.032	0.030	0.027	0.026	0.022	0.022
15	3.8	0.025	0.025	0.027	0.027	0.028	0.028	0.028	0.028	0.028	0.027	0.026	0.026	0.024	0.024	0.021	0.021	0.018	0.017
10	5.7	0.016	0.016	0.017	0.018	0.018	0.019	0.019	0.019	0.019	0.019	0.018	0.018	0.017	0.017	0.015	0.015	0.013	0.013
7	8.2	0.011	0.011	0.012	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.012	0.012	0.011	0.011	0.010	0.010
5	11.5	0.007	0.007	0.008	0.008	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.010	0.009	0.009	0.009	0.009	0.008	0.008
4	14.5	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.007
3	19.5	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
2	30.0	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006
1.5	41.8	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.003

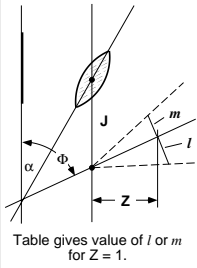


Table gives value of l or m for $Z = 1$.

TABLE VIIIa: DEPTH OF FIELD FOR f/4 — by angle

By Angle		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
f-number = 4 a/f = 1/1500		LENS TILT		1	2	5	10	20	30	40	50	60
		J/f	α									
Other Combinations:		10000	0.006	0.7° to 1.9°	1.0° to 26.0°	1.5° to 176.2°	1.8° to 177.3°	2.0° to 177.6°	2.0° to 177.7°	2.1° to 177.8°	2.1° to 177.8°	2.1° to 177.8°
		1000	0.057	1.0° to 1.0°	1.8° to 2.2°	4.1° to 6.5°	6.9° to 18.3°	10.5° to 84.9°	12.9° to 133.0°	14.6° to 145.9°	16.0° to 151.3°	17.2° to 154.5°
		200	0.29	1.0° to 1.0°	2.0° to 2.0°	4.8° to 5.2°	9.2° to 11.0°	17.0° to 24.2°	23.9° to 39.7°	30.2° to 56.4°	36.2° to 72.8°	42.1° to 87.4°
		100	0.57	1.0° to 1.0°	2.0° to 2.0°	4.9° to 5.1°	9.6° to 10.4°	18.4° to 21.8°	26.7° to 34.2°	34.6° to 47.1°	42.3° to 60.0°	50.0° to 72.6°
1.4	1/500	50	1.1	n/a	2.0° to 2.0°	5.0° to 5.0°	9.8° to 10.2°	19.2° to 20.8°	28.3° to 31.9°	37.2° to 43.2°	45.9° to 54.6°	54.7° to 65.9°
2.0	1/750	30	1.9	n/a	2.0° to 2.0°	5.0° to 5.0°	9.9° to 10.1°	19.6° to 20.5°	29.0° to 31.1°	38.3° to 41.8°	47.6° to 52.6°	56.8° to 63.4°
2.8	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	10.0° to 10.0°	19.7° to 20.3°	29.4° to 30.6°	38.9° to 41.1°	48.4° to 51.7°	57.9° to 62.2°
4.0	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	10.0° to 10.0°	19.8° to 20.2°	29.6° to 30.5°	39.2° to 40.8°	48.8° to 51.2°	58.4° to 61.6°
5.7	1/2000	10	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.9° to 20.1°	29.7° to 30.3°	39.5° to 40.5°	49.3° to 50.8°	59.0° to 61.0°
8.0	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	20.0° to 20.0°	29.9° to 30.1°	39.7° to 40.3°	49.5° to 50.5°	59.3° to 60.7°
11	1/4000	5	11.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.8° to 40.2°	49.7° to 50.3°	59.6° to 60.4°
16	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	39.9° to 40.1°	49.8° to 50.2°	59.7° to 60.3°
23	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	39.9° to 40.1°	49.9° to 50.1°	59.8° to 60.2°
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	40.0° to 40.0°	50.0° to 50.0°	59.9° to 60.1°
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	60.0° to 60.0°
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS TILT		70	80	90	100	110	120	130	140	150
		J/f	α									
		10000	0.006	2.1° to 177.8°	2.1° to 177.8°	2.2° to 177.9°	2.2° to 177.9°	2.2° to 177.9°	2.2° to 177.9°	2.2° to 177.9°	2.3° to 177.9°	2.3° to 178.0°
		1000	0.057	18.3° to 156.6°	19.4° to 158.2°	20.6° to 159.5°	21.9° to 160.7°	23.5° to 161.8°	25.6° to 162.9°	28.7° to 164.1°	34.2° to 165.5°	46.9° to 167.2°
		200	0.29	48.2° to 99.6°	54.7° to 109.7°	62.0° to 118.1°	70.4° to 125.5°	80.4° to 132.0°	92.4° to 138.1°	106.8° to 144.0°	123.2° to 150.0°	140.0° to 156.3°
		100	0.57	57.9° to 84.4°	66.2° to 95.1°	75.1° to 105.0°	84.8° to 114.0°	95.5° to 122.3°	107.1° to 130.3°	119.6° to 138.0°	132.6° to 145.7°	145.5° to 153.5°
		50	1.1	63.7° to 76.9°	72.9° to 87.5°	82.4° to 97.6°	92.4° to 107.3°	102.9° to 116.5°	113.8° to 125.5°	125.1° to 134.3°	136.5° to 143.1°	147.8° to 151.9°
		30	1.9	66.2° to 74.1°	75.7° to 84.5°	85.4° to 94.6°	95.5° to 104.4°	105.8° to 114.0°	116.3° to 123.4°	127.0° to 132.7°	137.9° to 142.0°	148.7° to 151.2°
		20	2.9	67.5° to 72.6°	77.1° to 82.9°	87.0° to 93.1°	97.0° to 103.0°	107.2° to 112.7°	117.5° to 122.4°	128.0° to 131.9°	138.5° to 141.4°	149.1° to 150.9°
		15	3.8	68.1° to 71.9°	77.9° to 82.2°	87.7° to 92.3°	97.7° to 102.3°	107.9° to 112.1°	118.1° to 121.8°	128.5° to 131.5°	138.9° to 141.1°	149.3° to 150.7°
		10	5.7	68.8° to 71.3°	78.6° to 81.4°	88.5° to 91.5°	98.5° to 101.5°	108.6° to 111.4°	118.7° to 121.3°	128.9° to 131.0°	139.2° to 140.8°	149.5° to 150.5°
		7	8.2	69.2° to 70.8°	79.0° to 81.0°	89.0° to 91.1°	98.9° to 101.1°	109.0° to 111.0°	119.1° to 120.9°	129.2° to 130.8°	139.4° to 140.6°	149.6° to 150.4°
		5	11.5	69.4° to 70.6°	79.3° to 80.7°	89.3° to 90.7°	99.2° to 100.8°	109.3° to 110.7°	119.3° to 120.7°	129.4° to 130.6°	139.5° to 140.5°	149.7° to 150.3°
		4	14.5	69.6° to 70.4°	79.5° to 80.5°	89.4° to 90.6°	99.4° to 100.6°	109.4° to 110.6°	119.4° to 120.6°	129.5° to 130.5°	139.6° to 140.4°	149.7° to 150.3°
		3	19.5	69.7° to 70.3°	79.7° to 80.3°	89.6° to 90.4°	99.6° to 100.4°	109.5° to 110.5°	119.6° to 120.4°	129.6° to 130.4°	139.7° to 140.3°	149.7° to 150.3°
		2	30.0	69.9° to 70.1°	79.8° to 80.2°	89.8° to 90.2°	99.7° to 100.3°	109.7° to 110.3°	119.7° to 120.3°	129.7° to 130.3°	139.7° to 140.3°	149.8° to 150.2°
		1.5	41.8	69.9° to 70.1°	79.9° to 80.1°	89.9° to 90.1°	99.8° to 100.2°	109.8° to 110.2°	119.8° to 120.2°	129.8° to 130.2°	139.8° to 140.2°	149.8° to 150.2°
		1	90.0	n/a	n/a	n/a	100.0° to 100.0°	110.0° to 110.0°	120.0° to 120.0°	129.9° to 130.1°	139.9° to 140.1°	149.9° to 150.1°

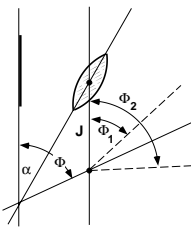


Table gives range from Φ₁ to Φ₂

TABLE VIIIb: DEPTH OF FIELD FOR f/4 — by depth of field fraction

Fractions f-number = 4 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																				
		LENS TILT		1		2		5		10		20		30		40		50		60		
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	
Other combinations:	10000	0.006	0.315	0.86	0.480	12.75	0.70	Inf.	0.83	Inf.	0.95	Inf.	1.06	Inf.	1.21	Inf.	1.45	Inf.	1.84	Inf.		
	1000	0.057	0.040	0.043	0.081	0.097	0.185	0.295	0.315	0.84	0.489	6.26	0.62	Inf.	0.74	Inf.	0.88	Inf.	1.07	Inf.		
	200	0.29	0.005	0.005	0.013	0.014	0.040	0.043	0.080	0.096	0.152	0.214	0.213	0.340	0.268	0.459	0.321	0.55	0.373	0.60		
	100	0.57	0.001	0.001	0.005	0.005	0.018	0.019	0.039	0.043	0.080	0.094	0.116	0.145	0.148	0.193	0.177	0.231	0.204	0.258		
	50	1.1	n/a	n/a	0.001	0.001	0.007	0.007	0.018	0.019	0.039	0.042	0.059	0.066	0.077	0.087	0.093	0.106	0.106	0.120		
30	1.9	n/a	n/a	0.000	0.000	0.003	0.003	0.009	0.009	0.022	0.023	0.034	0.037	0.046	0.049	0.056	0.060	0.064	0.069			
20	2.9	n/a	n/a	n/a	n/a	0.001	0.001	0.005	0.005	0.013	0.014	0.022	0.023	0.029	0.031	0.036	0.038	0.042	0.045			
15	3.8	n/a	n/a	n/a	n/a	0.000	0.000	0.003	0.003	0.009	0.009	0.015	0.016	0.021	0.022	0.027	0.028	0.031	0.032			
10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.005	0.005	0.009	0.009	0.013	0.013	0.017	0.017	0.020	0.021			
7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.005	0.005	0.008	0.008	0.011	0.011	0.013	0.013			
5.7	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.003	0.003	0.005	0.005	0.007	0.007	0.009	0.009			
8.0	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.003	0.003	0.005	0.005	0.006	0.006			
11	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.004			
16	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002			
23	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000			
	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			

Fractions f-number = 4 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																				
		LENS TILT		70		80		90		100		110		120		130		140		150		
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	
Other combinations:	10000	0.006	2.62	Inf.	4.72	Inf.	26.6	26.7	Inf.	4.73	Inf.	2.62	Inf.	1.84	Inf.	1.45	Inf.	1.21	Inf.	1.06		
	1000	0.057	1.35	17.77	1.80	4.85	2.66	2.67	4.81	1.81	17.29	1.35	Inf.	1.07	Inf.	0.88	Inf.	0.74	Inf.	0.62		
	200	0.29	0.426	0.60	0.479	0.58	0.53	0.53	0.58	0.483	0.61	0.430	0.60	0.378	0.56	0.326	0.471	0.275	0.353	0.220		
	100	0.57	0.229	0.273	0.250	0.275	0.266	0.267	0.275	0.253	0.275	0.233	0.264	0.210	0.239	0.184	0.202	0.155	0.156	0.124		
	50	1.1	0.118	0.129	0.127	0.134	0.133	0.134	0.135	0.130	0.132	0.122	0.125	0.112	0.113	0.099	0.096	0.084	0.076	0.067		
30	1.9	0.071	0.075	0.077	0.079	0.080	0.080	0.081	0.079	0.079	0.075	0.074	0.070	0.067	0.062	0.058	0.053	0.046	0.043			
20	2.9	0.047	0.049	0.051	0.052	0.053	0.053	0.054	0.053	0.053	0.051	0.050	0.048	0.045	0.043	0.039	0.037	0.032	0.031			
15	3.8	0.035	0.036	0.038	0.039	0.040	0.040	0.040	0.040	0.040	0.039	0.038	0.037	0.035	0.033	0.030	0.029	0.025	0.024			
10	5.7	0.023	0.023	0.025	0.025	0.026	0.026	0.027	0.027	0.027	0.026	0.026	0.025	0.024	0.023	0.022	0.021	0.018	0.018			
7	8.2	0.015	0.016	0.017	0.017	0.018	0.018	0.019	0.019	0.019	0.019	0.019	0.018	0.018	0.017	0.016	0.016	0.014	0.014			
5	11.5	0.010	0.010	0.012	0.012	0.013	0.013	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.012	0.012			
4	14.5	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.010			
3	19.5	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009			
2	30.0	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.007	0.008			
1.5	41.8	0.001	0.001	0.002	0.002	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.007			
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.004	0.004			

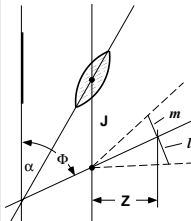


Table gives value of l or m for $Z = 1$.

TABLE IXa: DEPTH OF FIELD FOR f/5.6 — by angle

By Angle f-number = 5.6 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS J/f	TILT α	1	2	5	10	20	30	40	50	60
Other Combinations: f-number a/f	10000	0.006	0.6° to 2.8°	0.9° to 173.4°	1.2° to 177.8°	1.3° to 178.2°	1.4° to 178.3°	1.5° to 178.4°	1.5° to 178.4°	1.5° to 178.4°	1.5° to 178.4°	
	1000	0.057	0.9° to 1.1°	1.8° to 2.3°	3.8° to 7.3°	6.1° to 27.0°	8.8° to 134.4°	10.4° to 153.5°	11.5° to 158.6°	12.4° to 161.0°	13.1° to 162.5°	
	200	0.29	1.0° to 1.0°	2.0° to 2.0°	4.7° to 5.3°	8.9° to 11.4°	16.1° to 26.4°	22.1° to 45.1°	27.4° to 65.7°	32.4° to 84.5°	37.2° to 99.5°	
	100	0.57	1.0° to 1.0°	2.0° to 2.0°	4.9° to 5.1°	9.5° to 10.6°	17.9° to 22.7°	25.6° to 36.1°	32.7° to 50.4°	39.7° to 64.8°	46.6° to 78.3°	
	2.0	1/500	5.0	1.1	n/a	2.0° to 2.0°	5.0° to 5.0°	9.8° to 10.3°	18.9° to 21.2°	27.7° to 32.7°	36.1° to 44.6°	44.5° to 56.7°
	2.8	1/750	3.0	1.9	n/a	2.0° to 2.0°	5.0° to 5.0°	9.9° to 10.1°	19.4° to 20.6°	28.6° to 31.5°	37.7° to 42.6°	46.6° to 53.8°
	4.0	1/1000	2.0	2.9	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.6° to 20.4°	29.1° to 30.9°	38.5° to 41.6°	47.8° to 52.4°
	5.6	1/1500	1.5	3.8	n/a	n/a	5.0° to 5.0°	10.0° to 10.0°	19.8° to 20.3°	29.4° to 30.6°	38.9° to 41.1°	48.4° to 51.7°
	7.9	1/2000	1.0	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.9° to 20.1°	29.6° to 30.4°	39.3° to 40.7°	49.0° to 51.1°
	11	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.9° to 20.1°	29.8° to 30.2°	39.6° to 40.4°	49.3° to 50.7°
16	1/4000	5	11.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.8° to 40.2°	49.6° to 50.4°	
22	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.8° to 40.2°	49.7° to 50.3°	
32	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	39.9° to 40.1°	49.8° to 50.2°	
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	40.0° to 40.0°	50.0° to 50.1°	
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60.0° to 60.0°	
		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS J/f	TILT α	70	80	90	100	110	120	130	140	150
		10000	0.006	1.5° to 178.5°	1.5° to 178.5°	1.5° to 178.5°	1.5° to 178.5°	1.6° to 178.5°	1.6° to 178.5°	1.6° to 178.5°	1.6° to 178.5°	1.6° to 178.5°
		1000	0.057	13.8° to 163.5°	14.4° to 164.4°	15.0° to 165.1°	15.8° to 165.7°	16.6° to 166.3°	17.6° to 167.0°	19.1° to 167.7°	21.5° to 168.6°	26.6° to 169.7°
		200	0.29	42.1° to 110.9°	47.4° to 119.8°	53.4° to 126.8°	60.4° to 132.8°	69.1° to 138.1°	80.3° to 143.1°	95.1° to 147.9°	113.7° to 152.9°	134.3° to 158.2°
		100	0.57	53.8° to 90.5°	61.3° to 101.1°	69.6° to 110.5°	78.9° to 118.9°	89.4° to 126.6°	101.4° to 133.7°	114.7° to 140.7°	129.0° to 147.6°	143.4° to 154.7°
		50	1.1	61.3° to 79.8°	70.2° to 90.6°	79.5° to 100.6°	89.4° to 110.0°	99.9° to 119.0°	111.2° to 127.6°	122.9° to 135.9°	134.9° to 144.2°	146.9° to 152.6°
		30	1.9	64.7° to 75.7°	74.0° to 86.3°	83.6° to 96.4°	93.6° to 106.2°	104.0° to 115.6°	114.8° to 124.8°	125.8° to 133.8°	137.0° to 142.7°	148.1° to 151.7°
		20	2.9	66.5° to 73.7°	76.0° to 84.1°	85.8° to 94.3°	95.8° to 104.2°	106.0° to 113.8°	116.5° to 123.3°	127.2° to 132.6°	137.9° to 141.9°	148.7° to 151.2°
		15	3.8	67.4° to 72.7°	77.0° to 83.1°	86.8° to 93.2°	96.8° to 103.1°	107.0° to 112.9°	117.4° to 122.5°	127.9° to 132.0°	138.4° to 141.5°	149.0° to 151.0°
		10	5.7	68.3° to 71.8°	78.0° to 82.0°	87.9° to 92.1°	97.9° to 102.1°	108.0° to 112.0°	118.2° to 121.8°	128.5° to 131.4°	138.9° to 141.1°	149.3° to 150.7°
		7	8.2	68.8° to 71.2°	78.7° to 81.4°	88.5° to 91.5°	98.5° to 101.5°	108.6° to 111.4°	118.7° to 121.3°	128.9° to 131.1°	139.2° to 140.8°	149.4° to 150.6°
		5	11.5	69.2° to 70.8°	79.1° to 80.9°	89.0° to 91.0°	98.9° to 101.1°	109.0° to 111.0°	119.0° to 121.0°	129.2° to 130.8°	139.3° to 140.6°	149.5° to 150.5°
		4	14.5	69.4° to 70.6°	79.3° to 80.7°	89.2° to 90.8°	99.2° to 100.8°	109.2° to 110.8°	119.2° to 120.8°	129.3° to 130.7°	139.4° to 140.6°	149.6° to 150.4°
		3	19.5	69.6° to 70.4°	79.5° to 80.5°	89.4° to 90.6°	99.4° to 100.6°	109.4° to 110.6°	119.4° to 120.6°	129.4° to 130.6°	139.5° to 140.5°	149.6° to 150.4°
		2	30.0	69.8° to 70.2°	79.7° to 80.3°	89.7° to 90.3°	99.6° to 100.4°	109.6° to 110.4°	119.6° to 120.4°	129.6° to 130.4°	139.6° to 140.4°	149.7° to 150.3°
		1.5	41.8	69.9° to 70.1°	79.9° to 80.1°	89.8° to 90.2°	99.8° to 100.2°	109.7° to 110.3°	119.7° to 120.3°	129.7° to 130.3°	139.7° to 140.3°	149.7° to 150.3°
		1	90.0	n/a	n/a	n/a	100.0° to 100.0°	110.0° to 110.0°	119.9° to 120.1°	129.9° to 130.1°	139.9° to 140.1°	149.8° to 150.2°

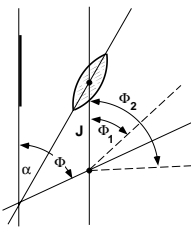


Table gives range from Φ₁ to Φ₂

TABLE IXb: DEPTH OF FIELD FOR f/5.6 — by depth of field fraction

Fractions f-number = 5.6 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
Other combinations: f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	0.391	1.83	0.56	Inf.	0.77	Inf.	0.88	Inf.	0.98	Inf.	1.09	Inf.	1.24	Inf.	1.48	Inf.
		1000	0.057	0.055	0.062	0.109	0.141	0.241	0.468	0.392	1.76	0.58	Inf.	0.71	Inf.	0.84	Inf.	1.01	Inf.	1.23	Inf.
		200	0.29	0.007	0.007	0.019	0.020	0.055	0.062	0.109	0.140	0.201	0.326	0.278	0.54	0.347	0.75	0.415	0.90	0.485	0.95
		100	0.57	0.001	0.001	0.007	0.007	0.025	0.026	0.054	0.061	0.108	0.137	0.155	0.215	0.198	0.287	0.237	0.345	0.275	0.382
2.0	1/500	50	1.1	n/a	n/a	0.001	0.001	0.010	0.010	0.025	0.026	0.054	0.060	0.081	0.094	0.105	0.126	0.126	0.152	0.146	0.172
2.8	1/750	30	1.9	n/a	n/a	0.000	0.000	0.004	0.004	0.013	0.013	0.031	0.033	0.047	0.052	0.063	0.070	0.077	0.086	0.089	0.098
4.0	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.001	0.001	0.007	0.007	0.019	0.019	0.030	0.032	0.041	0.044	0.050	0.054	0.059	0.063
5.6	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.000	0.000	0.004	0.004	0.013	0.013	0.021	0.022	0.030	0.031	0.037	0.039	0.044	0.046
7.9	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.007	0.007	0.012	0.013	0.018	0.019	0.023	0.024	0.028	0.029
11	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.003	0.003	0.007	0.007	0.011	0.011	0.015	0.015	0.018	0.019
16	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.004	0.004	0.007	0.007	0.009	0.010	0.012	0.012
22	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.004	0.004	0.007	0.007	0.009	0.009
32	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002	0.004	0.004	0.005	0.005
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																		
		70		80		90		100		110		120		130		140		150		
Other combinations: f-number	a/f	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	
				10000	0.006	2.70	Inf.	4.98	Inf.	37.2	37.5	Inf.	4.98	Inf.	2.70	Inf.	1.88	Inf.	1.48	Inf.
		1000	0.057	1.59	Inf.	2.24	10.26	3.72	3.75	10.07	2.25	Inf.	1.60	Inf.	1.24	Inf.	1.01	Inf.	0.85	Inf.
		200	0.29	0.56	0.92	0.65	0.84	0.74	0.75	0.84	0.66	0.92	0.57	0.96	0.492	0.91	0.422	0.77	0.355	0.56
		100	0.57	0.310	0.397	0.343	0.393	0.372	0.375	0.393	0.348	0.400	0.316	0.389	0.282	0.356	0.246	0.301	0.207	0.231
50	1.1	0.163	0.184	0.176	0.189	0.186	0.187	0.190	0.180	0.189	0.168	0.180	0.153	0.163	0.135	0.139	0.115	0.109	0.092	
30	1.9	0.099	0.107	0.106	0.111	0.111	0.112	0.113	0.110	0.111	0.104	0.106	0.096	0.096	0.086	0.082	0.074	0.066	0.060	
20	2.9	0.066	0.069	0.071	0.073	0.074	0.075	0.075	0.074	0.074	0.071	0.070	0.066	0.064	0.060	0.056	0.052	0.046	0.043	
15	3.8	0.049	0.051	0.053	0.054	0.056	0.056	0.057	0.056	0.056	0.054	0.053	0.051	0.049	0.046	0.043	0.041	0.036	0.034	
10	5.7	0.032	0.033	0.035	0.035	0.037	0.037	0.038	0.038	0.038	0.037	0.036	0.035	0.034	0.033	0.030	0.029	0.026	0.025	
7	8.2	0.021	0.022	0.024	0.024	0.026	0.026	0.027	0.026	0.027	0.027	0.026	0.026	0.025	0.024	0.023	0.022	0.020	0.020	
5	11.5	0.014	0.015	0.016	0.017	0.018	0.018	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.018	0.018	0.017	0.016	
4	14.5	0.011	0.011	0.012	0.013	0.014	0.014	0.015	0.015	0.015	0.016	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	
3	19.5	0.007	0.007	0.009	0.009	0.010	0.010	0.011	0.011	0.011	0.012	0.012	0.013	0.012	0.013	0.013	0.013	0.013	0.013	
2	30.0	0.003	0.003	0.004	0.004	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.009	0.009	0.009	0.010	0.010	0.011	0.011	
1.5	41.8	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.007	0.007	0.009	0.009	0.010	
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.006	0.006	

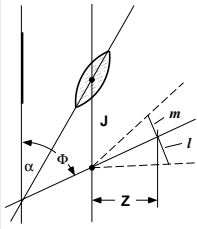


Table gives value of l or m for $Z = 1$.

f/5.6

TABLE Xa: DEPTH OF FIELD FOR f8 — by angle

By Angle f-number = 8 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)											
		LENS TILT J/f α		1	2	5	10	20	30	40	50	60	
Other Combinations: f-number a/f	10000	0.006	0.5° to 13.1°	0.7° to 177.7°	0.9° to 178.6°	1.0° to 178.8°	1.0° to 178.9°	1.0° to 178.9°	1.0° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	
	1000	0.057	0.9° to 1.1°	1.7° to 2.4°	3.4° to 9.2°	5.2° to 69.7°	7.1° to 158.9°	8.1° to 164.5°	8.8° to 166.5°	9.3° to 167.5°	9.7° to 168.2°	9.7° to 168.2°	
	200	0.29	1.0° to 1.0°	1.9° to 2.1°	4.6° to 5.5°	8.5° to 12.1°	14.8° to 30.4°	19.8° to 55.9°	24.1° to 82.5°	27.9° to 102.6°	31.5° to 116.0°	31.5° to 116.0°	
	100	0.57	1.0° to 1.0°	2.0° to 2.0°	4.8° to 5.2°	9.2° to 10.9°	17.1° to 24.1°	24.0° to 39.5°	30.3° to 56.2°	36.3° to 72.7°	42.2° to 87.3°	42.2° to 87.3°	
	2.8	1/500	50	1.1	n/a	2.0° to 2.0°	4.9° to 5.1°	9.7° to 10.4°	18.5° to 21.7°	26.8° to 34.0°	34.7° to 46.9°	42.4° to 59.9°	50.1° to 72.5°
	4.0	1/750	30	1.9	n/a	2.0° to 2.0°	5.0° to 5.0°	9.8° to 10.2°	19.2° to 20.9°	28.1° to 32.2°	36.8° to 43.8°	45.3° to 55.5°	53.9° to 67.1°
	5.7	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.5° to 20.5°	28.8° to 31.3°	37.9° to 42.3°	46.9° to 53.5°	55.9° to 64.5°
	8.0	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.7° to 20.4°	29.1° to 30.9°	38.5° to 41.7°	47.7° to 52.5°	57.0° to 63.3°
	11	1/2000	10	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.8° to 20.2°	29.5° to 30.5°	39.1° to 41.0°	48.6° to 51.5°	58.0° to 62.1°
	16	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.9° to 20.1°	29.7° to 30.3°	39.4° to 40.6°	49.1° to 51.0°	58.7° to 61.3°
23	1/4000	5	11.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.8° to 30.2°	39.7° to 40.4°	49.4° to 50.6°	59.2° to 60.9°	
32	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.8° to 40.2°	49.6° to 50.4°	59.4° to 60.6°	
45	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	39.9° to 40.1°	49.8° to 50.2°	59.6° to 60.4°	
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	40.0° to 40.0°	49.9° to 50.1°	59.8° to 60.2°	
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	60.0° to 60.0°	
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)									
		70	80	90	100	110	120	130	140	150	
10000	0.006	1.1° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	1.1° to 178.9°	1.1° to 179.0°	1.1° to 179.0°	
1000	0.057	10.0° to 168.7°	10.3° to 169.1°	10.7° to 169.4°	11.0° to 169.8°	11.4° to 170.1°	11.9° to 170.5°	12.6° to 170.9°	13.6° to 171.3°	15.6° to 172.0°	
200	0.29	35.1° to 125.2°	39.0° to 131.8°	43.3° to 137.0°	48.4° to 141.4°	55.0° to 145.2°	63.9° to 148.9°	77.0° to 152.5°	96.7° to 156.3°	123.1° to 160.5°	
100	0.57	48.3° to 99.6°	54.8° to 109.7°	62.1° to 118.2°	70.4° to 125.5°	80.3° to 132.1°	92.3° to 138.2°	106.7° to 144.2°	123.0° to 150.1°	139.8° to 156.4°	
50	1.1	58.0° to 84.3°	66.3° to 95.1°	75.1° to 105.0°	84.8° to 114.0°	95.4° to 122.5°	107.0° to 130.4°	119.5° to 138.1°	132.4° to 145.8°	145.4° to 153.7°	
30	1.9	62.6° to 78.3°	71.6° to 89.0°	81.0° to 99.1°	90.9° to 108.7°	101.4° to 117.9°	112.4° to 126.7°	123.9° to 135.3°	135.6° to 143.8°	147.2° to 152.4°	
20	2.9	65.0° to 75.4°	74.3° to 85.9°	84.0° to 96.1°	93.9° to 105.9°	104.3° to 115.4°	115.0° to 124.6°	125.9° to 133.7°	137.0° to 142.7°	148.1° to 151.7°	
15	3.8	66.3° to 73.9°	75.8° to 84.4°	85.5° to 94.6°	95.4° to 104.5°	105.7° to 114.1°	116.2° to 123.6°	126.9° to 132.9°	137.7° to 142.1°	148.5° to 151.4°	
10	5.7	67.6° to 72.5°	77.2° to 82.9°	87.0° to 93.0°	97.0° to 103.0°	107.1° to 112.8°	117.4° to 122.5°	127.9° to 132.0°	138.4° to 141.5°	148.9° to 151.0°	
7	8.2	68.4° to 71.7°	78.1° to 82.0°	87.9° to 92.1°	97.9° to 102.1°	107.9° to 112.0°	118.1° to 121.8°	128.4° to 131.5°	138.8° to 141.2°	149.2° to 150.8°	
5	11.5	68.9° to 71.1°	78.7° to 81.3°	88.5° to 91.5°	98.5° to 101.5°	108.5° to 111.5°	118.6° to 121.4°	128.8° to 131.2°	139.1° to 140.9°	149.3° to 150.7°	
4	14.5	69.2° to 70.8°	79.0° to 81.0°	88.9° to 91.2°	98.8° to 101.2°	108.8° to 111.2°	118.9° to 121.1°	129.0° to 131.0°	139.2° to 140.8°	149.4° to 150.6°	
3	19.5	69.5° to 70.6°	79.3° to 80.7°	89.2° to 90.8°	99.1° to 100.9°	109.1° to 110.9°	119.1° to 120.9°	129.2° to 130.8°	139.3° to 140.7°	149.5° to 150.5°	
2	30.0	69.7° to 70.3°	79.6° to 80.4°	89.5° to 90.5°	99.5° to 100.5°	109.4° to 110.6°	119.4° to 120.6°	129.4° to 130.6°	139.5° to 140.5°	149.5° to 150.5°	
1.5	41.8	69.9° to 70.1°	79.8° to 80.2°	89.7° to 90.3°	99.7° to 100.3°	109.6° to 110.4°	119.6° to 120.4°	129.5° to 130.5°	139.6° to 140.4°	149.6° to 150.4°	
1	90.0	n/a	n/a	n/a	100.0° to 100.0°	110.0° to 110.0°	119.9° to 120.1°	129.9° to 130.1°	139.8° to 140.2°	149.8° to 150.2°	

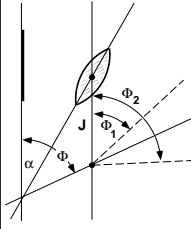


Table gives range from Φ₁ to Φ₂.

TABLE Xb: DEPTH OF FIELD FOR f/8 — by depth of field fraction

Fractions f-number = 8 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																				
		LENS TILT		1		2		5		10		20		30		40		50		60		
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	
Other combinations:	10000	0.006	0.478	12.32	0.65	Inf.	0.82	Inf.	0.91	Inf.	1.01	Inf.	1.11	Inf.	1.26	Inf.	1.50	Inf.	1.92	Inf.		
	1000	0.057	0.076	0.091	0.149	0.214	0.312	0.84	0.480	9.85	0.67	Inf.	0.80	Inf.	0.94	Inf.	1.12	Inf.	1.39	Inf.		
	200	0.29	0.009	0.010	0.026	0.028	0.076	0.091	0.149	0.213	0.265	0.54	0.359	0.97	0.444	1.42	0.53	1.71	0.63	1.72		
	100	0.57	0.002	0.002	0.009	0.010	0.035	0.038	0.076	0.090	0.148	0.207	0.210	0.334	0.265	0.453	0.318	0.55	0.370	0.60		
2.8	1/500	50	1.1	n/a	n/a	0.002	0.002	0.014	0.014	0.035	0.038	0.075	0.089	0.112	0.140	0.144	0.188	0.174	0.227	0.202	0.256	
4.0	1/750	30	1.9	n/a	n/a	0.000	0.000	0.005	0.005	0.018	0.019	0.043	0.047	0.067	0.076	0.088	0.103	0.107	0.126	0.124	0.143	
5.7	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.002	0.002	0.009	0.010	0.026	0.028	0.043	0.046	0.058	0.064	0.071	0.079	0.083	0.091	
8.0	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.000	0.000	0.005	0.005	0.018	0.019	0.030	0.032	0.042	0.045	0.052	0.057	0.061	0.066	
11	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.009	0.010	0.018	0.018	0.026	0.027	0.033	0.035	0.040	0.042	
16	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.005	0.005	0.010	0.010	0.016	0.016	0.021	0.022	0.026	0.027	
23	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.005	0.005	0.009	0.010	0.013	0.014	0.017	0.017	
32	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.003	0.003	0.006	0.006	0.009	0.009	0.012	0.013	
45	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.003	0.003	0.005	0.005	0.008	0.008	
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.001	0.002	0.002	0.003	0.003	
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Fractions f-number = 8 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																			
		LENS TILT		70		80		90		100		110		120		130		140		150	
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
Other combinations:	10000	0.006	2.76	Inf.	5.19	Inf.	53.1	53.6	Inf.	5.19	Inf.	2.76	Inf.	1.92	Inf.	1.50	Inf.	1.26	Inf.	1.11	Inf.
	1000	0.057	1.84	Inf.	2.74	63.3	5.31	5.36	56.5	2.76	Inf.	1.85	Inf.	1.40	Inf.	1.13	Inf.	0.95	Inf.	0.81	Inf.
	200	0.29	0.74	1.53	0.88	1.29	1.06	1.07	1.28	0.89	1.52	0.75	1.72	0.64	1.73	0.54	1.46	0.455	1.01	0.370	Inf.
	100	0.57	0.423	0.60	0.477	0.58	0.53	0.54	0.58	0.485	0.61	0.432	0.61	0.380	0.56	0.329	0.477	0.278	0.360	0.224	Inf.
50	1.1	0.227	0.271	0.248	0.275	0.265	0.268	0.276	0.254	0.277	0.235	0.266	0.212	0.243	0.187	0.207	0.159	0.162	0.128	Inf.	
30	1.9	0.139	0.155	0.151	0.161	0.159	0.161	0.163	0.156	0.161	0.147	0.154	0.135	0.140	0.120	0.121	0.103	0.096	0.083	Inf.	
20	2.9	0.093	0.100	0.101	0.105	0.106	0.107	0.108	0.105	0.107	0.101	0.102	0.094	0.093	0.084	0.081	0.073	0.066	0.060	Inf.	
15	3.8	0.069	0.073	0.075	0.078	0.079	0.080	0.081	0.080	0.080	0.077	0.077	0.072	0.071	0.066	0.062	0.057	0.051	0.048	Inf.	
10	5.7	0.045	0.047	0.049	0.051	0.053	0.053	0.054	0.054	0.054	0.053	0.052	0.050	0.049	0.046	0.044	0.041	0.037	0.035	Inf.	
7	8.2	0.030	0.031	0.034	0.035	0.036	0.037	0.038	0.038	0.038	0.038	0.038	0.037	0.036	0.035	0.033	0.032	0.029	0.028	Inf.	
5	11.5	0.020	0.021	0.023	0.024	0.025	0.026	0.027	0.027	0.028	0.028	0.028	0.028	0.027	0.027	0.026	0.025	0.024	0.023	Inf.	
4	14.5	0.015	0.016	0.018	0.018	0.020	0.020	0.021	0.022	0.023	0.022	0.023	0.023	0.023	0.022	0.022	0.022	0.021	0.021	Inf.	
3	19.5	0.010	0.010	0.012	0.012	0.014	0.014	0.016	0.016	0.017	0.017	0.018	0.018	0.018	0.018	0.019	0.018	0.019	0.018	Inf.	
2	30.0	0.005	0.005	0.006	0.006	0.008	0.008	0.010	0.010	0.011	0.011	0.012	0.012	0.014	0.013	0.015	0.015	0.016	0.016	Inf.	
1.5	41.8	0.002	0.002	0.003	0.003	0.004	0.004	0.006	0.006	0.007	0.007	0.009	0.009	0.010	0.010	0.012	0.012	0.014	0.014	Inf.	
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.005	0.005	0.008	0.008	Inf.	

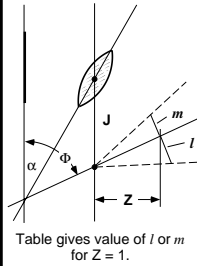


Table gives value of l or m for Z = 1.

TABLE XIa: DEPTH OF FIELD FOR f/11 — by angle

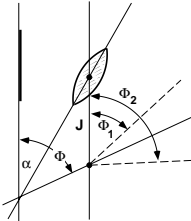
By Angle f-number = 11 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS TILT J/f α		1	2	5	10	20	30	40	50	60
Other Combinations: f-number a/f	10000	0.006	0.4° to 176.4°	0.6° to 178.7°	0.7° to 179.1°	0.7° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	
	1000	0.057	0.9° to 1.1°	1.6° to 2.6°	3.1° to 13.4°	4.4° to 148.5°	5.7° to 167.7°	6.3° to 169.9°	6.7° to 170.8°	7.0° to 171.3°	7.3° to 171.6°	
	200	0.29	1.0° to 1.0°	1.9° to 2.1°	4.5° to 5.6°	8.1° to 13.2°	13.5° to 37.3°	17.5° to 74.3°	20.8° to 105.0°	23.7° to 122.0°	26.3° to 131.7°	
	100	0.57	1.0° to 1.0°	2.0° to 2.0°	4.8° to 5.3°	9.0° to 11.3°	16.2° to 26.0°	22.3° to 44.5°	27.7° to 64.8°	32.7° to 83.6°	37.6° to 98.7°	
3.9	1/500	50	1.1	n/a	2.0° to 2.0°	4.9° to 5.1°	9.5° to 10.5°	18.0° to 22.5°	25.8° to 35.8°	33.0° to 50.0°	40.0° to 64.3°	47.0° to 77.8°
5.5	1/750	30	1.9	n/a	2.0° to 2.0°	5.0° to 5.0°	9.8° to 10.3°	18.9° to 21.3°	27.4° to 33.1°	35.7° to 45.4°	43.7° to 57.8°	51.8° to 70.0°
7.8	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.3° to 20.8°	28.4° to 31.9°	37.1° to 43.3°	45.8° to 54.9°	54.5° to 66.3°
11	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.5° to 20.5°	28.8° to 31.3°	37.9° to 42.3°	46.9° to 53.5°	55.9° to 64.6°
16	1/2000	10	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.7° to 20.3°	29.3° to 30.7°	38.7° to 41.4°	48.0° to 52.1°	57.3° to 62.9°
22	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.9° to 20.1°	29.6° to 30.4°	39.2° to 40.8°	48.7° to 51.3°	58.2° to 61.9°
31	1/4000	5	11.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.8° to 30.2°	39.5° to 40.5°	49.2° to 50.8°	58.8° to 61.2°
44	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.7° to 40.3°	49.4° to 50.6°	59.2° to 60.9°
62	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	30.0° to 30.0°	39.8° to 40.2°	49.7° to 50.3°	59.5° to 60.5°
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	40.0° to 40.0°	49.9° to 50.1°	59.8° to 60.2°
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	59.9° to 60.1°
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
 <p>Table gives range from Φ_1 to Φ_2.</p>		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS TILT J/f α		70	80	90	100	110	120	130	140	150
		10000	0.006	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°	0.8° to 179.2°
		1000	0.057	7.5° to 171.9°	7.6° to 172.1°	7.8° to 172.3°	8.0° to 172.5°	8.2° to 172.7°	8.5° to 172.9°	8.8° to 173.1°	9.3° to 173.4°	10.2° to 173.8°
		200	0.29	28.9° to 137.9°	31.5° to 142.4°	34.5° to 145.9°	38.0° to 148.9°	42.3° to 151.6°	48.4° to 154.1°	57.8° to 156.8°	74.3° to 159.6°	104.1° to 162.8°
		100	0.57	42.6° to 110.3°	48.0° to 119.2°	53.9° to 126.5°	61.0° to 132.5°	69.7° to 137.9°	81.0° to 142.9°	95.7° to 147.8°	114.1° to 152.8°	134.4° to 158.2°
		50	1.1	54.1° to 90.0°	61.7° to 100.8°	70.0° to 110.3°	79.2° to 118.7°	89.7° to 126.5°	101.6° to 133.7°	114.8° to 140.7°	129.0° to 147.7°	143.3° to 154.8°
		30	1.9	60.0° to 81.6°	68.6° to 92.4°	77.7° to 102.5°	87.5° to 111.8°	98.0° to 120.6°	109.3° to 128.9°	121.3° to 137.0°	133.7° to 145.1°	146.1° to 153.2°
		20	2.9	63.3° to 77.5°	72.3° to 88.2°	81.7° to 98.4°	91.6° to 108.1°	102.0° to 117.3°	113.0° to 126.3°	124.3° to 135.0°	135.8° to 143.6°	147.3° to 152.3°
		15	3.8	64.9° to 75.5°	74.2° to 86.1°	83.8° to 96.3°	93.7° to 106.1°	104.0° to 115.6°	114.7° to 124.9°	125.7° to 133.9°	136.8° to 142.9°	147.9° to 151.9°
		10	5.7	66.7° to 73.5°	76.2° to 84.0°	85.9° to 94.2°	95.8° to 104.1°	106.0° to 113.9°	116.4° to 123.4°	127.0° to 132.8°	137.8° to 142.1°	148.5° to 151.4°
		7	8.2	67.8° to 72.3°	77.4° to 82.7°	87.1° to 92.9°	97.1° to 102.9°	107.2° to 112.8°	117.4° to 122.5°	127.8° to 132.1°	138.3° to 141.6°	148.8° to 151.1°
		5	11.5	68.5° to 71.6°	78.2° to 81.8°	88.0° to 92.0°	97.9° to 102.1°	107.9° to 112.0°	118.1° to 121.9°	128.4° to 131.6°	138.7° to 141.3°	149.1° to 150.9°
		4	14.5	68.9° to 71.2°	78.6° to 81.4°	88.4° to 91.6°	98.3° to 101.7°	108.3° to 111.7°	118.4° to 121.5°	128.6° to 131.4°	138.9° to 141.1°	149.2° to 150.8°
		3	19.5	69.3° to 70.8°	79.1° to 81.0°	88.9° to 91.1°	98.8° to 101.2°	108.7° to 111.3°	118.8° to 121.2°	128.9° to 131.1°	139.1° to 140.9°	149.3° to 150.7°
2	30.0	69.7° to 70.3°	79.5° to 80.5°	89.4° to 90.6°	99.3° to 100.7°	109.2° to 110.8°	119.2° to 120.8°	129.2° to 130.8°	139.3° to 140.7°	149.4° to 150.6°		
1.5	41.8	69.9° to 70.1°	79.8° to 80.2°	89.7° to 90.4°	99.5° to 100.5°	109.5° to 110.5°	119.4° to 120.6°	129.4° to 130.6°	139.4° to 140.6°	149.4° to 150.6°		
1	90.0	n/a	n/a	n/a	100.0° to 100.0°	110.0° to 110.0°	119.9° to 120.1°	129.8° to 130.2°	139.8° to 140.2°	149.7° to 150.3°		

TABLE XIb: DEPTH OF FIELD FOR f/11 — by depth of field fraction

Fractions f-number = 11 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (ϕ - DEGREES)																			
		LENS TILT		1		2		5		10		20		30		40		50		60	
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
Other combinations:		10000	0.006	0.56	Inf.	0.72	Inf.	0.87	Inf.	0.94	Inf.	1.02	Inf.	1.12	Inf.	1.27	Inf.	1.51	Inf.	1.94	Inf.
		1000	0.057	0.101	0.129	0.193	0.321	0.383	1.69	0.56	Inf.	0.74	Inf.	0.88	Inf.	1.02	Inf.	1.22	Inf.	1.52	Inf.
		200	0.29	0.013	0.013	0.036	0.039	0.101	0.129	0.193	0.318	0.333	0.91	0.442	1.96	0.54	3.34	0.65	4.03	0.77	3.50
		100	0.57	0.002	0.002	0.013	0.013	0.047	0.053	0.101	0.129	0.193	0.308	0.269	0.52	0.338	0.72	0.405	0.87	0.475	0.92
3.9	1/500	50	1.1	n/a	n/a	0.002	0.002	0.019	0.019	0.047	0.053	0.101	0.126	0.148	0.202	0.190	0.273	0.230	0.332	0.267	0.370
5.5	1/750	30	1.9	n/a	n/a	0.000	0.000	0.007	0.007	0.024	0.026	0.058	0.066	0.089	0.107	0.118	0.146	0.143	0.179	0.167	0.203
7.8	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.002	0.002	0.013	0.013	0.036	0.039	0.058	0.065	0.078	0.089	0.096	0.111	0.112	0.128
11	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.001	0.001	0.007	0.007	0.024	0.026	0.041	0.045	0.057	0.063	0.071	0.079	0.083	0.092
16	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.013	0.013	0.024	0.025	0.035	0.037	0.045	0.048	0.054	0.058
22	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.006	0.006	0.014	0.014	0.022	0.023	0.029	0.031	0.036	0.038
31	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.007	0.007	0.013	0.013	0.018	0.019	0.023	0.024
44	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.004	0.004	0.008	0.009	0.013	0.013	0.017	0.018
62	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.004	0.004	0.007	0.007	0.011	0.011
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.002	0.002	0.004	0.004
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Fractions f-number = 11 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (ϕ - DEGREES)																			
		LENS TILT		70		80		90		100		110		120		130		140		150	
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
Other combinations:		10000	0.006	2.80	Inf.	5.33	Inf.	72.8	73.9	Inf.	5.34	Inf.	2.81	Inf.	1.94	Inf.	1.51	Inf.	1.27	Inf.	1.12
		1000	0.057	2.05	Inf.	3.19	Inf.	7.28	7.39	Inf.	3.21	Inf.	2.06	Inf.	1.52	Inf.	1.22	Inf.	1.02	Inf.	0.88
		200	0.29	0.93	2.63	1.15	1.94	1.46	1.48	1.91	1.16	2.59	0.94	3.47	0.78	4.06	0.66	3.45	0.55	2.07	0.455
		100	0.57	0.55	0.90	0.64	0.83	0.73	0.74	0.82	0.65	0.90	0.56	0.94	0.489	0.89	0.420	0.76	0.354	0.56	0.287
50	1.1	50	1.1	0.302	0.387	0.335	0.385	0.364	0.369	0.385	0.344	0.394	0.314	0.384	0.281	0.354	0.246	0.302	0.209	0.234	0.169
30	1.9	30	1.9	0.187	0.218	0.205	0.224	0.218	0.221	0.226	0.212	0.226	0.199	0.218	0.181	0.199	0.161	0.171	0.138	0.136	0.112
20	2.9	20	2.9	0.126	0.140	0.137	0.146	0.145	0.147	0.149	0.144	0.149	0.137	0.143	0.127	0.131	0.114	0.114	0.098	0.093	0.081
15	3.8	15	3.8	0.094	0.102	0.103	0.108	0.109	0.110	0.112	0.109	0.111	0.105	0.107	0.098	0.099	0.089	0.087	0.078	0.072	0.065
10	5.7	10	5.7	0.062	0.065	0.068	0.070	0.072	0.073	0.074	0.074	0.075	0.072	0.072	0.068	0.068	0.063	0.061	0.056	0.052	0.048
7	8.2	7	8.2	0.042	0.043	0.046	0.048	0.050	0.051	0.052	0.052	0.053	0.052	0.052	0.050	0.050	0.047	0.046	0.043	0.040	0.038
5	11.5	5	11.5	0.028	0.029	0.032	0.033	0.035	0.035	0.037	0.037	0.038	0.038	0.039	0.038	0.038	0.036	0.036	0.034	0.033	0.032
4	14.5	4	14.5	0.021	0.022	0.024	0.025	0.027	0.028	0.030	0.030	0.031	0.031	0.032	0.031	0.032	0.031	0.032	0.031	0.030	0.029
3	19.5	3	19.5	0.014	0.014	0.017	0.017	0.019	0.020	0.022	0.022	0.023	0.023	0.025	0.024	0.025	0.025	0.026	0.025	0.026	0.025
2	30.0	2	30.0	0.006	0.006	0.009	0.009	0.011	0.011	0.013	0.013	0.015	0.015	0.017	0.017	0.019	0.019	0.020	0.020	0.022	0.022
1.5	41.8	1.5	41.8	0.003	0.003	0.004	0.004	0.006	0.006	0.008	0.008	0.010	0.010	0.012	0.012	0.014	0.014	0.017	0.017	0.020	0.020
1	90.0	1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.002	0.002	0.004	0.004	0.007	0.007	0.011	0.011

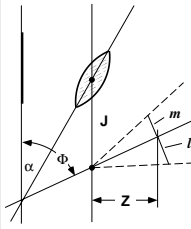


Table gives value of l or m for $Z = 1$.

TABLE XIIa: DEPTH OF FIELD FOR f/16 — by angle

By Angle f-number = 16 a/f = 1/1500		LENS TILT		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)									
		J/f	α	1	2	5	10	20	30	40	50	60	
Other Combinations: f-number a/f	10000	0.006	0.4° to 178.8°	0.4° to 179.3°	0.5° to 179.4°	0.5° to 179.4°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	
	1000	0.057	0.9° to 1.2°	1.5° to 3.1°	2.6° to 48.2°	3.6° to 168.7°	4.3° to 172.9°	4.7° to 173.7°	4.9° to 174.0°	5.0° to 174.2°	5.1° to 174.4°	5.1° to 174.4°	
	200	0.29	1.0° to 1.0°	1.9° to 2.1°	4.3° to 6.0°	7.4° to 15.4°	11.8° to 57.0°	14.7° to 111.1°	17.0° to 133.2°	18.8° to 142.4°	20.5° to 147.4°	20.5° to 147.4°	
	100	0.57	1.0° to 1.0°	2.0° to 2.0°	4.7° to 5.4°	8.6° to 12.0°	14.9° to 30.1°	20.0° to 55.3°	24.2° to 82.1°	28.0° to 102.5°	31.7° to 116.0°	31.7° to 116.0°	
	5.7	1/500	1.1	n/a	2.0° to 2.0°	4.9° to 5.1°	9.3° to 10.8°	17.3° to 23.8°	24.2° to 39.1°	30.5° to 55.8°	36.5° to 72.3°	42.5° to 87.1°	
	8.0	1/750	1.9	n/a	2.0° to 2.0°	4.9° to 5.1°	9.7° to 10.4°	18.4° to 22.0°	26.4° to 34.7°	34.0° to 48.2°	41.3° to 61.9°	48.6° to 75.1°	
	11	1/1000	2.9	n/a	n/a	5.0° to 5.0°	9.8° to 10.2°	19.0° to 21.1°	27.7° to 32.8°	36.0° to 45.0°	44.1° to 57.3°	52.2° to 69.5°	
	16	1/1500	3.8	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.3° to 20.7°	28.3° to 31.9°	37.0° to 43.5°	45.6° to 55.2°	54.1° to 66.8°	
	23	1/2000	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.6° to 20.4°	29.0° to 31.1°	38.2° to 42.0°	47.2° to 53.1°	56.2° to 64.2°	
	32	1/3000	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.8° to 20.2°	29.4° to 30.6°	38.9° to 41.2°	48.2° to 52.0°	57.5° to 62.7°	
45	1/4000	11.5	n/a	n/a	n/a	n/a	19.9° to 20.1°	29.7° to 30.3°	39.3° to 40.7°	48.8° to 51.2°	58.3° to 61.8°		
64	1/6000	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.8° to 30.2°	39.6° to 40.5°	49.2° to 50.8°	58.8° to 61.3°		
91	1/8500	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.8° to 40.2°	49.5° to 50.5°	59.2° to 60.8°		
	3	30.0	n/a	n/a	n/a	n/a	n/a	n/a	40.0° to 40.0°	49.9° to 50.1°	59.7° to 60.3°		
	1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	59.9° to 60.1°		
	1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		

		LENS TILT		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)									
		J/f	α	70	80	90	100	110	120	130	140	150	
		10000	0.006	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.5° to 179.5°	0.6° to 179.5°	
		1000	0.057	5.2° to 174.5°	5.3° to 174.6°	5.4° to 174.7°	5.5° to 174.8°	5.6° to 174.9°	5.7° to 175.0°	5.9° to 175.1°	6.1° to 175.2°	6.4° to 175.4°	
		200	0.29	22.1° to 150.7°	23.7° to 153.2°	25.3° to 155.1°	27.3° to 156.8°	29.7° to 158.4°	32.9° to 160.0°	37.8° to 161.6°	46.6° to 163.5°	67.4° to 165.7°	
		100	0.57	35.3° to 125.2°	39.2° to 131.9°	43.5° to 137.2°	48.6° to 141.5°	55.0° to 145.4°	63.9° to 149.1°	76.8° to 152.7°	96.3° to 156.5°	122.6° to 160.7°	
		5.0	1.1	48.5° to 99.5°	55.0° to 109.7°	62.2° to 118.3°	70.5° to 125.7°	80.3° to 132.3°	92.2° to 138.5°	106.4° to 144.4°	122.6° to 150.4°	139.4° to 156.6°	
		3.0	1.9	56.1° to 87.2°	63.9° to 98.1°	72.4° to 107.9°	81.8° to 116.7°	92.3° to 124.8°	104.0° to 132.4°	116.8° to 139.7°	130.4° to 147.0°	144.0° to 154.5°	
		2.0	2.9	60.4° to 81.1°	69.0° to 92.0°	78.1° to 102.1°	87.8° to 111.6°	98.3° to 120.4°	109.5° to 128.8°	121.4° to 137.0°	133.7° to 145.1°	146.0° to 153.3°	
		1.5	3.8	62.8° to 78.1°	71.7° to 88.9°	81.0° to 99.1°	90.9° to 108.8°	101.2° to 118.1°	112.2° to 126.9°	123.6° to 135.5°	135.2° to 144.1°	146.9° to 152.6°	
		1.0	5.7	65.3° to 75.2°	74.5° to 85.8°	84.0° to 96.1°	93.9° to 106.0°	104.1° to 115.6°	114.7° to 124.9°	125.6° to 134.0°	136.7° to 143.0°	147.8° to 152.0°	
		0.7	8.2	66.8° to 73.4°	76.2° to 83.9°	85.9° to 94.2°	95.7° to 104.3°	105.8° to 114.0°	116.2° to 123.6°	126.8° to 133.0°	137.5° to 142.3°	148.3° to 151.6°	
		0.5	11.5	67.8° to 72.3°	77.4° to 82.7°	87.1° to 93.0°	97.0° to 103.1°	107.0° to 113.0°	117.2° to 122.7°	127.6° to 132.3°	138.1° to 141.8°	148.6° to 151.3°	
		0.4	14.5	68.4° to 71.7°	78.0° to 82.1°	87.7° to 92.3°	97.6° to 102.4°	107.6° to 112.4°	117.7° to 122.2°	128.0° to 132.0°	138.3° to 141.6°	148.8° to 151.2°	
		0.3	19.5	68.9° to 71.1°	78.6° to 81.4°	88.4° to 91.6°	98.2° to 101.8°	108.2° to 111.8°	118.2° to 121.8°	128.4° to 131.6°	138.6° to 141.3°	148.9° to 151.0°	
		0.2	30.0	69.5° to 70.5°	79.3° to 80.7°	89.1° to 90.9°	98.9° to 101.1°	108.8° to 111.2°	118.8° to 121.2°	128.8° to 131.2°	138.9° to 141.1°	149.1° to 150.9°	
		0.15	41.8	69.8° to 70.2°	79.7° to 80.4°	89.5° to 90.5°	99.3° to 100.7°	109.2° to 110.8°	119.1° to 120.9°	129.1° to 130.9°	139.1° to 140.9°	149.2° to 150.8°	
		0.1	90.0	n/a	n/a	n/a	100.0° to 100.0°	109.9° to 110.1°	119.8° to 120.2°	129.7° to 130.3°	139.6° to 140.4°	149.5° to 150.5°	

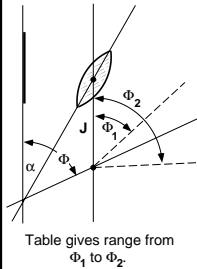


Table gives range from Φ_1 to Φ_2 .

TABLE XIIb: DEPTH OF FIELD FOR f/16 — by depth of field fraction

Fractions f-number = 16 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
Other combinations: f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	0.65	Inf.	0.79	Inf.	0.90	Inf.	0.96	Inf.	1.03	Inf.	1.13	Inf.	1.28	Inf.	1.53	Inf.
		1000	0.057	0.141	0.201	0.258	0.55	0.474	10.77	0.65	Inf.	0.82	Inf.	0.95	Inf.	1.09	Inf.	1.30	Inf.	1.64	Inf.
		200	0.29	0.018	0.019	0.051	0.058	0.141	0.200	0.258	0.54	0.423	2.20	0.55	12.84	0.66	Inf.	0.79	Inf.	0.95	25.9
		100	0.57	0.003	0.003	0.018	0.019	0.067	0.079	0.141	0.199	0.259	0.52	0.354	0.95	0.439	1.40	0.53	1.70	0.62	1.71
5.7	1/500	50	1.1	n/a	n/a	0.003	0.003	0.027	0.029	0.067	0.079	0.140	0.195	0.203	0.321	0.259	0.442	0.312	0.54	0.365	0.59
8.0	1/750	30	1.9	n/a	n/a	0.000	0.000	0.010	0.011	0.035	0.038	0.082	0.100	0.125	0.164	0.164	0.224	0.200	0.275	0.233	0.311
11	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.003	0.003	0.018	0.019	0.051	0.058	0.082	0.097	0.110	0.135	0.135	0.167	0.158	0.193
16	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.001	0.001	0.010	0.011	0.035	0.038	0.059	0.066	0.081	0.094	0.101	0.118	0.119	0.138
23	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.003	0.003	0.018	0.019	0.035	0.038	0.050	0.055	0.064	0.072	0.077	0.085
32	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.009	0.009	0.020	0.021	0.031	0.033	0.042	0.045	0.051	0.055
45	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.003	0.003	0.011	0.011	0.018	0.019	0.026	0.028	0.034	0.035
64	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.006	0.006	0.012	0.013	0.018	0.019	0.025	0.026
91	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.006	0.006	0.011	0.011	0.015	0.016
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.003	0.003	0.006	0.006
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																			
		70		80		90		100		110		120		130		140		150			
Other combinations: f-number	a/f	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l				
				10000	0.006	2.84	Inf.	5.46	Inf.	105.5	107.8	Inf.	5.46	Inf.	2.84	Inf.	1.96	Inf.	1.53	Inf.	1.28
		1000	0.057	2.26	Inf.	3.71	Inf.	10.55	10.78	Inf.	3.73	Inf.	2.27	Inf.	1.65	Inf.	1.31	Inf.	1.10	Inf.	0.95
		200	0.29	1.18	6.52	1.53	3.35	2.11	2.16	3.26	1.55	6.24	1.20	22.8	0.97	Inf.	0.80	Inf.	0.68	15.29	0.56
		100	0.57	0.74	1.53	0.88	1.30	1.06	1.08	1.27	0.90	1.52	0.76	1.72	0.64	1.74	0.55	1.48	0.460	1.04	0.376
50	1.1	0.419	0.60	0.473	0.58	0.53	0.54	0.58	0.489	0.61	0.437	0.61	0.386	0.57	0.335	0.488	0.284	0.374	0.231		
30	1.9	0.264	0.330	0.292	0.333	0.316	0.323	0.333	0.305	0.340	0.281	0.332	0.254	0.306	0.224	0.264	0.192	0.209	0.156		
20	2.9	0.179	0.209	0.197	0.216	0.211	0.215	0.219	0.208	0.221	0.196	0.214	0.180	0.197	0.161	0.172	0.139	0.139	0.115		
15	3.8	0.135	0.151	0.148	0.159	0.158	0.161	0.163	0.158	0.164	0.151	0.159	0.140	0.147	0.126	0.130	0.111	0.107	0.092		
10	5.7	0.088	0.096	0.098	0.103	0.104	0.107	0.109	0.107	0.109	0.104	0.107	0.098	0.100	0.091	0.090	0.081	0.077	0.069		
7	8.2	0.060	0.064	0.067	0.070	0.072	0.074	0.076	0.076	0.077	0.075	0.076	0.072	0.073	0.068	0.067	0.062	0.059	0.055		
5	11.5	0.040	0.042	0.046	0.048	0.051	0.052	0.054	0.054	0.056	0.055	0.056	0.055	0.055	0.053	0.052	0.050	0.048	0.046		
4	14.5	0.030	0.031	0.035	0.036	0.040	0.040	0.043	0.043	0.045	0.045	0.046	0.045	0.046	0.045	0.045	0.043	0.043	0.041		
3	19.5	0.020	0.021	0.024	0.025	0.028	0.029	0.031	0.032	0.034	0.034	0.036	0.036	0.037	0.036	0.037	0.036	0.038	0.036		
2	30.0	0.009	0.009	0.013	0.013	0.016	0.016	0.019	0.019	0.022	0.022	0.025	0.025	0.027	0.027	0.030	0.029	0.032	0.032		
1.5	41.8	0.004	0.004	0.006	0.006	0.009	0.009	0.012	0.012	0.015	0.015	0.018	0.018	0.021	0.021	0.024	0.024	0.029	0.029		
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.001	0.001	0.003	0.003	0.006	0.006	0.010	0.010	0.016	0.016		

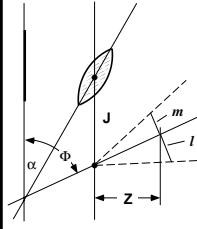


Table gives value of l or m for $Z = 1$.

TABLE XIIIa: DEPTH OF FIELD FOR f/22 — by angle

By Angle f-number = 22 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS J/f	TILT α	1	2	5	10	20	30	40	50	60
Other Combinations: f-number a/f	10000	0.006	0.3° to 179.4°	0.3° to 179.5°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	
	1000	0.057	0.8° to 1.3°	1.4° to 3.9°	2.2° to 162.2°	2.9° to 173.7°	3.3° to 175.3°	3.5° to 175.6°	3.7° to 175.8°	3.7° to 175.9°	3.8° to 176.0°	
	200	0.29	1.0° to 1.0°	1.9° to 2.2°	4.1° to 6.5°	6.8° to 19.3°	10.2° to 98.4°	12.3° to 140.0°	13.9° to 150.2°	15.1° to 154.7°	16.2° to 157.2°	
	100	0.57	1.0° to 1.0°	1.9° to 2.1°	4.6° to 5.6°	8.2° to 13.0°	13.7° to 36.7°	17.7° to 73.6°	21.0° to 104.6°	23.9° to 122.0°	26.5° to 131.8°	
	7.8	1/500	50	1.1	n/a	2.0° to 2.0°	4.8° to 5.2°	9.1° to 11.1°	16.4° to 25.6°	22.6° to 43.9°	28.0° to 64.2°	33.0° to 83.2°
11	1/750	30	1.9	n/a	2.0° to 2.0°	4.9° to 5.1°	9.5° to 10.5°	17.8° to 22.8°	25.3° to 36.8°	32.1° to 52.0°	38.7° to 67.3°	45.2° to 81.6°
16	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	9.7° to 10.3°	18.7° to 21.6°	26.9° to 34.0°	34.6° to 47.1°	42.2° to 60.5°	49.7° to 73.4°
22	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.9° to 10.1°	19.1° to 21.0°	27.7° to 32.7°	36.0° to 44.9°	44.1° to 57.3°	52.2° to 69.6°
31	1/2000	10	5.7	n/a	n/a	n/a	10.0° to 10.0°	19.5° to 20.5°	28.7° to 31.5°	37.5° to 42.9°	46.2° to 54.4°	54.8° to 65.9°
44	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.8° to 20.3°	29.2° to 30.8°	38.4° to 41.7°	47.5° to 52.8°	56.5° to 63.8°
62	1/4000	5	11.5	n/a	n/a	n/a	n/a	19.9° to 21.1°	29.6° to 30.4°	39.1° to 41.0°	48.4° to 51.7°	57.7° to 62.4°
88	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.8° to 30.2°	39.4° to 40.6°	48.9° to 51.2°	58.3° to 61.8°
124	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.7° to 40.3°	49.4° to 50.7°	59.0° to 61.1°
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	39.9° to 40.1°	49.8° to 50.2°	59.6° to 60.4°
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	59.9° to 60.1°
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS J/f		TILT α	PLANE OF SHARP FOCUS TILT (Φ - DEGREES)								
			70	80	90	100	110	120	130	140	150
10000	0.006	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°	0.4° to 179.6°
1000	0.057	3.9° to 176.1°	3.9° to 176.1°	4.0° to 176.2°	4.0° to 176.2°	4.1° to 176.3°	4.1° to 176.3°	4.2° to 176.4°	4.3° to 176.4°	4.3° to 176.4°	4.5° to 176.6°
200	0.29	17.1° to 159.0°	18.1° to 160.3°	19.1° to 161.4°	20.2° to 162.4°	21.5° to 163.4°	23.2° to 164.4°	25.7° to 165.4°	30.0° to 166.6°	30.0° to 166.6°	39.6° to 168.1°
100	0.57	29.1° to 138.1°	31.7° to 142.6°	34.7° to 146.1°	38.1° to 149.1°	42.5° to 151.8°	48.5° to 154.4°	57.8° to 157.0°	73.9° to 159.8°	73.9° to 159.8°	103.3° to 163.0°
50	1.1	42.9° to 110.3°	48.2° to 119.4°	54.2° to 126.6°	61.1° to 132.8°	69.7° to 138.2°	80.8° to 143.2°	95.3° to 148.1°	113.5° to 153.1°	113.5° to 153.1°	133.8° to 158.4°
30	1.9	51.8° to 94.1°	58.8° to 104.8°	66.6° to 114.0°	75.3° to 122.1°	85.4° to 129.4°	97.3° to 136.1°	110.9° to 142.7°	125.9° to 149.2°	125.9° to 149.2°	141.3° to 155.9°
20	2.9	57.3° to 85.6°	65.3° to 96.6°	73.9° to 106.5°	83.3° to 115.6°	93.7° to 123.9°	105.2° to 131.7°	117.8° to 139.3°	131.0° to 146.8°	131.0° to 146.8°	144.3° to 154.4°
15	3.8	60.3° to 81.3°	68.8° to 92.3°	77.8° to 102.5°	87.4° to 112.0°	97.8° to 120.8°	109.0° to 129.3°	120.9° to 137.4°	133.2° to 145.4°	133.2° to 145.4°	145.7° to 153.5°
10	5.7	63.6° to 77.2°	72.5° to 88.0°	81.9° to 98.4°	91.6° to 108.2°	101.9° to 117.6°	112.6° to 126.6°	123.9° to 135.4°	135.4° to 144.0°	135.4° to 144.0°	146.9° to 152.7°
7	8.2	65.6° to 74.8°	74.9° to 85.5°	84.3° to 95.8°	94.1° to 105.8°	104.3° to 115.5°	114.8° to 124.9°	125.6° to 134.1°	136.6° to 143.1°	136.6° to 143.1°	147.6° to 152.1°
5	11.5	67.0° to 73.2°	76.5° to 83.7°	86.0° to 94.1°	95.8° to 104.2°	105.9° to 114.1°	116.1° to 123.7°	126.7° to 133.1°	137.3° to 142.5°	137.3° to 142.5°	148.1° to 151.8°
4	14.5	67.8° to 72.3°	77.3° to 82.8°	86.9° to 93.2°	96.7° to 103.4°	106.7° to 113.3°	116.8° to 123.1°	127.2° to 132.7°	137.7° to 142.2°	137.7° to 142.2°	148.3° to 151.6°
3	19.5	68.5° to 71.5°	78.1° to 81.9°	87.8° to 92.3°	97.6° to 102.5°	107.5° to 112.5°	117.5° to 122.4°	127.8° to 132.2°	138.1° to 141.8°	138.1° to 141.8°	148.5° to 151.4°
2	30.0	69.3° to 70.7°	79.0° to 81.0°	88.8° to 91.3°	98.5° to 101.5°	108.4° to 111.6°	118.3° to 121.7°	128.4° to 131.6°	138.5° to 141.5°	138.5° to 141.5°	148.7° to 151.2°
1.5	41.8	69.7° to 70.3°	79.5° to 80.5°	89.3° to 90.7°	99.1° to 100.9°	108.9° to 111.1°	118.8° to 121.2°	128.7° to 131.3°	138.8° to 141.2°	138.8° to 141.2°	148.9° to 151.1°
1	90.0	n/a	n/a	n/a	100.0° to 100.0°	109.9° to 110.1°	119.8° to 120.2°	129.7° to 130.3°	139.5° to 140.5°	139.5° to 140.5°	149.4° to 150.6°

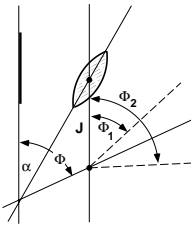


Table gives range from Φ₁ to Φ₂

TABLE XIIIb: DEPTH OF FIELD FOR f/22 — by depth of field fraction

Fractions f-number = 22 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
Other combinations: f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	0.71	Inf.	0.83	Inf.	0.93	Inf.	0.98	Inf.	1.04	Inf.	1.14	Inf.	1.29	Inf.	1.53	Inf.
		1000	0.057	0.183	0.300	0.323	0.96	0.55	Inf.	0.72	Inf.	0.87	Inf.	1.00	Inf.	1.14	Inf.	1.36	Inf.	1.72	Inf.
		200	0.29	0.025	0.027	0.069	0.082	0.183	0.299	0.323	0.94	0.51	14.24	0.64	Inf.	0.76	Inf.	0.91	Inf.	1.11	Inf.
		100	0.57	0.005	0.005	0.025	0.027	0.090	0.113	0.183	0.297	0.325	0.88	0.435	1.90	0.54	3.28	0.64	4.01	0.76	3.51
7.8	1/500	50	1.1	n/a	n/a	0.005	0.005	0.036	0.040	0.090	0.113	0.183	0.289	0.261	0.495	0.331	0.70	0.398	0.85	0.468	0.92
11	1/750	30	1.9	n/a	n/a	0.000	0.000	0.014	0.015	0.047	0.053	0.110	0.143	0.165	0.239	0.215	0.331	0.261	0.407	0.306	0.456
16	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.005	0.005	0.025	0.027	0.069	0.081	0.109	0.139	0.146	0.194	0.179	0.241	0.211	0.276
22	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.001	0.001	0.014	0.015	0.047	0.053	0.079	0.094	0.108	0.133	0.135	0.168	0.159	0.195
31	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.005	0.005	0.025	0.027	0.047	0.052	0.068	0.078	0.087	0.101	0.104	0.120
44	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.012	0.013	0.027	0.029	0.042	0.046	0.057	0.063	0.070	0.077
62	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.005	0.005	0.014	0.015	0.025	0.027	0.036	0.038	0.046	0.049
88	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.008	0.009	0.017	0.017	0.025	0.027	0.034	0.036
124	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.003	0.003	0.008	0.009	0.015	0.015	0.021	0.022
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.004	0.005	0.008	0.009
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.002	0.002
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (φ - DEGREES)																			
		70		80		90		100		110		120		130		140		150			
Other combinations: f-number	a/f	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	2.86	Inf.	5.53	Inf.	144.5	148.8	Inf.	5.54	Inf.	2.86	Inf.	1.97	Inf.	1.53	Inf.	1.29
		1000	0.057	2.41	Inf.	4.10	Inf.	14.45	14.88	Inf.	4.13	Inf.	2.42	Inf.	1.73	Inf.	1.37	Inf.	1.15	Inf.	1.00
		200	0.29	1.41	59.6	1.90	5.95	2.89	2.98	5.65	1.94	40.4	1.43	Inf.	1.13	Inf.	0.93	Inf.	0.78	Inf.	0.66
		100	0.57	0.92	2.64	1.14	1.96	1.45	1.49	1.90	1.17	2.57	0.95	3.45	0.79	4.07	0.66	3.50	0.56	2.12	0.462
50	1.1	0.54	0.90	0.63	0.83	0.72	0.74	0.82	0.65	0.90	0.57	0.94	0.496	0.90	0.427	0.78	0.362	0.58	0.296		
30	1.9	0.350	0.475	0.393	0.469	0.433	0.446	0.467	0.413	0.486	0.374	0.484	0.334	0.452	0.293	0.391	0.251	0.306	0.205		
20	2.9	0.240	0.296	0.266	0.302	0.288	0.297	0.304	0.283	0.311	0.263	0.305	0.240	0.283	0.213	0.247	0.184	0.199	0.152		
15	3.8	0.181	0.213	0.200	0.222	0.216	0.222	0.226	0.216	0.229	0.204	0.224	0.188	0.209	0.169	0.184	0.148	0.152	0.124		
10	5.7	0.120	0.134	0.133	0.143	0.143	0.147	0.150	0.147	0.152	0.142	0.149	0.133	0.140	0.122	0.126	0.109	0.108	0.094		
7	8.2	0.081	0.089	0.091	0.097	0.099	0.102	0.104	0.104	0.107	0.103	0.106	0.099	0.101	0.093	0.094	0.084	0.083	0.075		
5	11.5	0.055	0.059	0.063	0.066	0.069	0.071	0.074	0.074	0.077	0.076	0.078	0.075	0.076	0.072	0.073	0.068	0.067	0.062		
4	14.5	0.041	0.044	0.048	0.050	0.054	0.056	0.059	0.059	0.062	0.062	0.064	0.062	0.064	0.061	0.062	0.059	0.059	0.056		
3	19.5	0.027	0.029	0.033	0.035	0.039	0.040	0.043	0.044	0.047	0.047	0.050	0.049	0.051	0.050	0.052	0.050	0.052	0.050		
2	30.0	0.013	0.013	0.017	0.018	0.022	0.022	0.026	0.027	0.030	0.030	0.034	0.034	0.037	0.037	0.041	0.040	0.045	0.043		
1.5	41.8	0.005	0.005	0.008	0.009	0.012	0.012	0.016	0.016	0.020	0.020	0.024	0.024	0.029	0.029	0.034	0.033	0.040	0.039		
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.002	0.002	0.004	0.004	0.008	0.008	0.013	0.013	0.022	0.022		

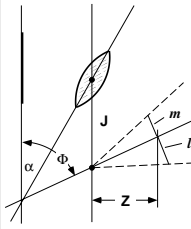


Table gives value of l or m for $Z = 1$.

f/22

TABLE XIVa: DEPTH OF FIELD FOR f32 — by angle

By Angle f-number = 32 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)											
		LENS TILT J/f α		1	2	5	10	20	30	40	50	60	
Other Combinations: f-number a/f	10000	0.006	0.2° to 179.6°	0.2° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°		
	1000	0.057	0.8° to 1.5°	1.2° to 7.1°	1.8° to 174.2°	2.2° to 176.4°	2.4° to 177.0°	2.5° to 177.1°	2.6° to 177.2°	2.6° to 177.3°	2.7° to 177.3°		
	200	0.29	1.0° to 1.0°	1.8° to 2.3°	3.8° to 7.5°	5.9° to 32.7°	8.4° to 146.2°	9.7° to 158.6°	10.6° to 162.2°	11.3° to 164.0°	11.9° to 165.1°		
	100	0.57	1.0° to 1.0°	1.9° to 2.1°	4.4° to 5.9°	7.6° to 15.0°	12.0° to 55.5°	14.9° to 110.4°	17.2° to 133.1°	19.1° to 142.5°	20.7° to 147.6°		
	11	1/500	50	1.1	n/a	2.0° to 2.0°	4.7° to 5.3°	8.8° to 11.7°	15.2° to 29.4°	20.3° to 54.3°	24.6° to 81.2°	28.4° to 102.1°	32.0° to 116.0°
	16	1/750	30	1.9	n/a	2.0° to 2.0°	4.9° to 5.1°	9.3° to 10.8°	17.0° to 24.4°	23.6° to 40.9°	29.5° to 59.5°	34.9° to 77.5°	40.3° to 92.9°
	23	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	9.6° to 10.4°	18.1° to 22.4°	25.7° to 36.1°	32.6° to 51.1°	39.3° to 66.2°	45.9° to 80.5°
	32	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.8° to 10.2°	18.7° to 21.6°	26.8° to 34.1°	34.5° to 47.5°	41.8° to 61.2°	49.1° to 74.5°
	45	1/2000	10	5.7	n/a	n/a	n/a	9.9° to 10.1°	19.3° to 20.8°	28.1° to 32.2°	36.5° to 44.3°	44.6° to 56.6°	52.7° to 68.9°
	64	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.7° to 20.4°	28.9° to 31.2°	37.8° to 42.5°	46.5° to 54.1°	55.1° to 65.7°
91	1/4000	5	11.5	n/a	n/a	n/a	n/a	19.9° to 20.1°	29.4° to 30.6°	38.7° to 41.5°	47.8° to 52.5°	56.8° to 63.6°	
128	1/6000	4	14.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.7° to 30.4°	39.1° to 40.9°	48.4° to 51.7°	57.6° to 62.6°	
181	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.9° to 30.1°	39.6° to 40.5°	49.1° to 51.0°	58.5° to 61.6°	
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	39.9° to 40.1°	49.7° to 50.3°	59.4° to 60.6°	
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50.0° to 50.0°	59.8° to 60.2°	
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)									
		70	80	90	100	110	120	130	140	150	
10000	0.006	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	0.3° to 179.7°	
1000	0.057	2.7° to 177.3°	2.7° to 177.4°	2.7° to 177.4°	2.8° to 177.4°	2.8° to 177.4°	2.8° to 177.4°	2.8° to 177.4°	2.9° to 177.5°	3.0° to 177.6°	
200	0.29	12.5° to 165.9°	13.0° to 166.5°	13.5° to 167.1°	14.0° to 167.6°	14.6° to 168.1°	15.4° to 168.6°	16.5° to 169.2°	18.2° to 169.9°	21.7° to 170.8°	
100	0.57	22.3° to 150.9°	23.9° to 153.4°	25.6° to 155.4°	27.5° to 157.1°	29.9° to 158.7°	33.1° to 160.2°	37.9° to 161.9°	46.6° to 163.7°	66.8° to 165.9°	
50	1.1	35.7° to 125.4°	39.5° to 132.2°	43.8° to 137.5°	48.8° to 141.9°	55.2° to 145.8°	63.9° to 149.4°	76.5° to 153.0°	95.6° to 156.8°	121.6° to 161.0°	
30	1.9	45.7° to 105.3°	51.5° to 115.1°	58.0° to 123.2°	65.4° to 129.9°	74.5° to 135.9°	85.8° to 141.5°	100.1° to 146.8°	117.3° to 152.2°	135.9° to 157.9°	
20	2.9	52.6° to 93.1°	59.6° to 104.1°	67.4° to 113.5°	76.1° to 121.8°	86.1° to 129.2°	97.8° to 136.1°	111.2° to 142.7°	125.9° to 149.2°	141.1° to 156.0°	
15	3.8	56.5° to 86.9°	64.3° to 98.1°	72.7° to 108.0°	81.9° to 117.0°	92.1° to 125.2°	103.6° to 132.9°	116.2° to 140.3°	129.7° to 147.5°	143.4° to 154.9°	
10	5.7	60.9° to 80.7°	69.4° to 91.8°	78.3° to 102.2°	87.8° to 111.8°	98.1° to 120.8°	109.1° to 129.3°	120.8° to 137.6°	133.0° to 145.6°	145.4° to 153.8°	
7	8.2	63.8° to 77.0°	72.6° to 88.0°	81.8° to 98.5°	91.5° to 108.4°	101.6° to 117.9°	112.3° to 127.0°	123.4° to 135.8°	134.9° to 144.4°	146.5° to 153.0°	
5	11.5	65.8° to 74.7°	74.9° to 85.5°	84.3° to 96.0°	93.9° to 106.1°	103.9° to 115.9°	114.3° to 125.3°	125.1° to 134.5°	136.1° to 143.6°	147.2° to 152.6°	
4	14.5	66.8° to 73.5°	76.1° to 84.2°	85.5° to 94.7°	95.2° to 104.9°	105.1° to 114.8°	115.4° to 124.4°	125.9° to 133.8°	136.6° to 143.1°	147.5° to 152.3°	
3	19.5	67.9° to 72.3°	77.3° to 82.9°	86.8° to 93.3°	96.5° to 103.6°	106.3° to 113.7°	116.4° to 123.5°	126.7° to 133.1°	137.2° to 142.6°	147.8° to 152.1°	
2	30.0	69.0° to 71.0°	78.6° to 81.5°	88.2° to 91.9°	97.9° to 102.2°	107.6° to 112.4°	117.6° to 122.4°	127.6° to 132.4°	137.8° to 142.1°	148.1° to 151.8°	
1.5	41.8	69.6° to 70.4°	79.3° to 80.7°	89.0° to 91.0°	98.7° to 101.3°	108.4° to 111.6°	118.3° to 121.8°	128.2° to 131.8°	138.2° to 141.8°	148.3° to 151.6°	
1	90.0	n/a	n/a	n/a	100.0° to 100.0°	109.9° to 110.1°	119.7° to 120.3°	129.5° to 130.5°	139.3° to 140.7°	149.1° to 150.9°	

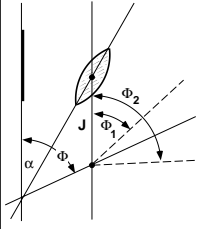


Table gives range from Φ_1 to Φ_2 .

TABLE XIVb: DEPTH OF FIELD FOR f/32 — by depth of field fraction

Fractions f-number = 32 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
		J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
Other combinations:		10000	0.006	0.78	Inf.	0.88	Inf.	0.95	Inf.	0.99	Inf.	1.05	Inf.	1.14	Inf.	1.29	Inf.	1.54	Inf.	1.98	Inf.
		1000	0.057	0.245	0.51	0.408	2.53	0.64	Inf.	0.79	Inf.	0.93	Inf.	1.04	Inf.	1.19	Inf.	1.42	Inf.	1.80	Inf.
		200	0.29	0.036	0.040	0.097	0.125	0.245	0.51	0.409	2.41	0.60	Inf.	0.74	Inf.	0.87	Inf.	1.04	Inf.	1.29	Inf.
		100	0.57	0.007	0.007	0.036	0.040	0.125	0.174	0.245	0.50	0.413	2.09	0.54	11.83	0.65	Inf.	0.78	Inf.	0.94	27.8
11	1/500	50	1.1	n/a	n/a	0.007	0.007	0.052	0.060	0.125	0.174	0.246	0.483	0.342	0.90	0.429	1.36	0.52	1.67	0.61	1.71
16	1/750	30	1.9	n/a	n/a	0.000	0.000	0.021	0.022	0.067	0.080	0.152	0.222	0.224	0.387	0.289	0.55	0.351	0.68	0.414	0.75
23	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.007	0.007	0.036	0.040	0.097	0.123	0.151	0.215	0.201	0.304	0.247	0.380	0.291	0.432
32	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.002	0.002	0.021	0.022	0.067	0.079	0.111	0.143	0.151	0.205	0.187	0.259	0.222	0.299
45	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.007	0.007	0.036	0.040	0.067	0.078	0.096	0.117	0.123	0.152	0.147	0.181
64	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.018	0.019	0.039	0.043	0.060	0.069	0.081	0.093	0.099	0.115
91	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.007	0.007	0.021	0.022	0.036	0.039	0.051	0.057	0.066	0.073
128	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.012	0.012	0.024	0.025	0.036	0.039	0.048	0.052
181	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.004	0.004	0.012	0.013	0.021	0.022	0.030	0.032
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.006	0.007	0.012	0.013
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.004	0.004
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
		70		80		90		100		110		120		130		140		150	
		m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
10000	0.006	2.88	Inf.	5.60	Inf.	209.	218.	Inf.	5.61	Inf.	2.88	Inf.	1.98	Inf.	1.54	Inf.	1.29	Inf.	1.14
1000	0.057	2.54	Inf.	4.50	Inf.	20.9	21.8	Inf.	4.54	Inf.	2.56	Inf.	1.81	Inf.	1.42	Inf.	1.19	Inf.	1.04
200	0.29	1.67	Inf.	2.40	16.75	4.18	4.36	14.49	2.46	Inf.	1.71	Inf.	1.31	Inf.	1.06	Inf.	0.89	Inf.	0.76
100	0.57	1.17	6.67	1.51	3.40	2.09	2.18	3.22	1.57	6.10	1.21	21.5	0.98	Inf.	0.81	Inf.	0.68	16.79	0.57
50	1.1	0.73	1.54	0.87	1.31	1.04	1.09	1.26	0.91	1.51	0.77	1.72	0.65	1.76	0.56	1.52	0.470	1.08	0.388
30	1.9	0.480	0.75	0.55	0.71	0.63	0.65	0.70	0.58	0.76	0.52	0.78	0.454	0.75	0.395	0.65	0.337	0.50	0.278
20	2.9	0.334	0.455	0.377	0.454	0.417	0.435	0.450	0.471	0.370	0.472	0.333	0.445	0.294	0.390	0.253	0.312	0.210	
15	3.8	0.255	0.323	0.285	0.331	0.312	0.326	0.333	0.311	0.344	0.289	0.341	0.264	0.321	0.236	0.284	0.206	0.233	0.173
10	5.7	0.170	0.201	0.190	0.213	0.207	0.216	0.219	0.212	0.225	0.203	0.223	0.190	0.211	0.173	0.191	0.154	0.162	0.132
7	8.2	0.116	0.132	0.131	0.143	0.143	0.149	0.152	0.151	0.157	0.148	0.157	0.141	0.151	0.132	0.140	0.120	0.123	0.107
5	11.5	0.079	0.087	0.090	0.097	0.100	0.105	0.108	0.109	0.113	0.109	0.114	0.107	0.113	0.103	0.107	0.097	0.099	0.089
4	14.5	0.059	0.064	0.070	0.074	0.078	0.082	0.086	0.087	0.091	0.089	0.094	0.090	0.094	0.088	0.092	0.085	0.088	0.080
3	19.5	0.039	0.042	0.048	0.051	0.056	0.058	0.063	0.064	0.068	0.068	0.072	0.071	0.075	0.072	0.076	0.072	0.076	0.072
2	30.0	0.018	0.019	0.025	0.026	0.031	0.033	0.038	0.039	0.044	0.044	0.049	0.049	0.054	0.054	0.059	0.058	0.065	0.063
1.5	41.8	0.007	0.008	0.012	0.013	0.017	0.018	0.023	0.024	0.029	0.030	0.035	0.036	0.042	0.042	0.049	0.049	0.058	0.057
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.003	0.003	0.006	0.006	0.011	0.012	0.019	0.020	0.032	0.032

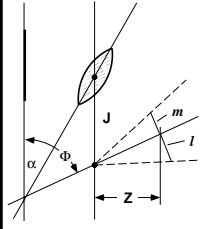


Table gives value of l or m for $Z = 1$.

f/32

TABLE XVa: DEPTH OF FIELD FOR f/45 — by angle

By Angle f-number = 45 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS J/f	TILT α	1	2	5	10	20	30	40	50	60
Other Combinations:		10000	0.006	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°
		1000	0.057	0.7° to 1.9°	1.0° to 117.5°	1.4° to 177.0°	1.7° to 177.7°	1.8° to 178.0°	1.9° to 178.0°	1.9° to 178.1°	1.9° to 178.1°	1.9° to 178.1°
		200	0.29	1.0° to 1.1°	1.7° to 2.4°	3.4° to 9.6°	5.1° to 99.3°	6.8° to 163.0°	7.6° to 167.0°	8.2° to 168.5°	8.6° to 169.3°	8.9° to 169.8°
		100	0.57	1.0° to 1.0°	1.9° to 2.1°	4.2° to 6.3°	6.9° to 18.9°	10.3° to 99.9°	12.4° to 141.4°	13.9° to 151.3°	15.1° to 155.6°	16.1° to 158.0°
16	1/500	50	1.1	n/a	2.0° to 2.0°	4.6° to 5.4°	8.3° to 12.6°	13.9° to 36.1°	17.9° to 73.7°	21.2° to 105.6°	24.0° to 123.2°	26.6° to 133.0°
23	1/750	30	1.9	n/a	2.0° to 2.0°	4.9° to 5.2°	9.1° to 11.2°	16.1° to 26.7°	21.7° to 47.7°	26.6° to 71.3°	31.0° to 92.0°	35.2° to 107.4°
32	1/1000	20	2.9	n/a	n/a	5.0° to 5.0°	9.5° to 10.6°	17.4° to 23.6°	24.3° to 39.4°	30.4° to 57.1°	36.1° to 74.7°	41.6° to 90.2°
45	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.7° to 10.3°	18.2° to 22.3°	25.7° to 36.1°	32.6° to 51.3°	39.2° to 66.8°	45.6° to 81.4°
64	1/2000	10	5.7	n/a	n/a	n/a	9.9° to 10.1°	19.0° to 21.1°	27.4° to 33.3°	35.2° to 46.3°	42.8° to 59.8°	50.2° to 73.0°
90	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.5° to 20.5°	28.5° to 31.8°	37.0° to 43.7°	45.2° to 55.9°	53.3° to 68.2°
127	1/4000	5	11.5	n/a	n/a	n/a	n/a	19.8° to 20.2°	29.2° to 30.9°	38.2° to 42.1°	46.9° to 53.6°	55.5° to 65.2°
180	1/6000	4	14.5	n/a	n/a	n/a	n/a	19.9° to 20.1°	29.5° to 30.5°	38.8° to 41.3°	47.8° to 52.5°	56.7° to 63.7°
255	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.8° to 30.2°	39.4° to 40.7°	48.7° to 51.4°	57.9° to 62.3°
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	39.9° to 40.1°	49.6° to 50.4°	59.2° to 60.9°
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	49.9° to 50.1°	59.8° to 60.3°
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS J/f	TILT α	70	80	90	100	110	120	130	140	150
		10000	0.006	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°	0.2° to 179.8°
		1000	0.057	1.9° to 178.1°	2.0° to 178.1°	2.0° to 178.1°	2.0° to 178.2°	2.0° to 178.2°	2.0° to 178.2°	2.0° to 178.2°	2.0° to 178.2°	2.1° to 178.3°
		200	0.29	9.2° to 170.2°	9.5° to 170.5°	9.7° to 170.8°	10.0° to 171.1°	10.3° to 171.3°	10.7° to 171.6°	11.2° to 172.0°	12.0° to 172.4°	13.4° to 172.9°
		100	0.57	17.1° to 159.7°	18.0° to 161.0°	19.0° to 162.1°	20.0° to 163.0°	21.3° to 164.0°	22.9° to 164.9°	25.2° to 165.9°	29.2° to 167.1°	38.0° to 168.5°
		50	1.1	29.1° to 139.2°	31.7° to 143.6°	34.5° to 147.1°	37.8° to 150.0°	41.9° to 152.6°	47.6° to 155.2°	56.4° to 157.7°	71.6° to 160.4°	99.9° to 163.6°
		30	1.9	39.4° to 118.4°	43.9° to 126.5°	48.9° to 132.8°	54.8° to 138.1°	62.1° to 142.7°	71.8° to 147.0°	85.3° to 151.2°	104.0° to 155.5°	127.1° to 160.2°
		20	2.9	47.3° to 103.0°	53.2° to 113.3°	59.8° to 121.7°	67.5° to 128.8°	76.6° to 135.1°	87.9° to 140.9°	101.8° to 146.5°	118.4° to 152.1°	136.3° to 157.9°
		15	3.8	52.1° to 94.3°	59.0° to 105.4°	66.5° to 114.8°	75.0° to 123.0°	84.7° to 130.3°	96.2° to 137.1°	109.5° to 143.6°	124.4° to 150.0°	140.0° to 156.6°
		10	5.7	57.7° to 85.4°	65.5° to 96.8°	73.9° to 107.0°	83.0° to 116.3°	93.1° to 124.7°	104.3° to 132.6°	116.6° to 140.2°	129.7° to 147.6°	143.2° to 155.1°
		7	8.2	61.5° to 80.1°	69.9° to 91.4°	78.7° to 102.0°	88.1° to 111.8°	98.1° to 120.9°	109.0° to 129.6°	120.5° to 137.9°	132.6° to 146.0°	144.9° to 154.2°
		5	11.5	64.2° to 76.7°	73.0° to 87.8°	82.0° to 98.4°	91.5° to 108.6°	101.5° to 118.2°	112.0° to 127.4°	122.9° to 136.2°	134.3° to 144.9°	145.9° to 153.5°
		4	14.5	65.6° to 74.9°	74.6° to 85.9°	83.8° to 96.6°	93.3° to 106.9°	103.1° to 116.7°	113.4° to 126.2°	124.1° to 135.3°	135.2° to 144.3°	146.4° to 153.2°
		3	19.5	67.1° to 73.2°	76.2° to 84.1°	85.6° to 94.7°	95.1° to 105.1°	104.9° to 115.1°	114.9° to 124.9°	125.4° to 134.4°	136.0° to 143.7°	146.9° to 152.8°
		2	30.0	68.6° to 71.5°	78.0° to 82.1°	87.5° to 92.6°	97.0° to 103.1°	106.7° to 113.4°	116.6° to 123.4°	126.6° to 133.3°	136.9° to 143.0°	147.4° to 152.5°
		1.5	41.8	69.4° to 70.6°	79.0° to 81.0°	88.6° to 91.5°	98.2° to 101.9°	107.8° to 112.3°	117.6° to 122.5°	127.4° to 132.6°	137.5° to 142.5°	147.6° to 152.3°
		1	90.0	n/a	n/a	n/a	n/a	99.9° to 100.1°	109.8° to 110.2°	119.6° to 120.4°	129.3° to 130.7°	148.7° to 151.3°

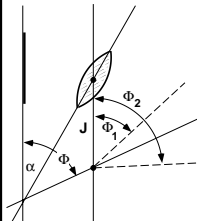


Table gives range from Φ_1 to Φ_2

TABLE XVb: DEPTH OF FIELD FOR f/45 — by depth of field fraction

Fractions f-number = 45 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
Other combinations: f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	0.83	Inf.	0.91	Inf.	0.97	Inf.	1.00	Inf.	1.05	Inf.	1.15	Inf.	1.30	Inf.	1.54	Inf.
		1000	0.057	0.312	0.92	0.490	Inf.	0.71	Inf.	0.84	Inf.	0.96	Inf.	1.07	Inf.	1.22	Inf.	1.45	Inf.	1.85	Inf.
		200	0.29	0.050	0.058	0.130	0.187	0.312	0.91	0.492	451.	0.69	Inf.	0.82	Inf.	0.96	Inf.	1.15	Inf.	1.43	Inf.
		100	0.57	0.009	0.010	0.050	0.058	0.167	0.267	0.312	0.90	0.500	16.45	0.63	Inf.	0.76	Inf.	0.91	Inf.	1.11	Inf.
16	1/500	50	1.1	n/a	n/a	0.009	0.010	0.071	0.086	0.167	0.265	0.314	0.85	0.428	1.91	0.53	3.44	0.64	4.32	0.76	3.78
23	1/750	30	1.9	n/a	n/a	0.000	0.000	0.029	0.032	0.091	0.117	0.200	0.345	0.290	0.64	0.371	0.95	0.450	1.18	0.53	1.26
32	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.009	0.010	0.050	0.058	0.130	0.183	0.201	0.330	0.264	0.478	0.324	0.60	0.384	0.67
45	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.002	0.002	0.029	0.032	0.091	0.116	0.149	0.213	0.201	0.311	0.250	0.394	0.297	0.453
64	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.009	0.010	0.050	0.057	0.091	0.114	0.130	0.172	0.166	0.224	0.200	0.266
90	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.025	0.027	0.054	0.062	0.083	0.100	0.110	0.136	0.136	0.167
127	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.009	0.010	0.029	0.032	0.050	0.057	0.071	0.082	0.090	0.105
180	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.003	0.003	0.017	0.018	0.033	0.036	0.050	0.056	0.067	0.075
255	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.006	0.006	0.017	0.018	0.029	0.032	0.042	0.046
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.003	0.003	0.009	0.009	0.017	0.018
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.005	0.005
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																			
		70		80		90		100		110		120		130		140		150			
Other combinations: f-number	a/f	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	2.89	Inf.	5.65	Inf.	291.	309.	Inf.	5.65	Inf.	2.89	Inf.	1.99	Inf.	1.55	Inf.	1.30
		1000	0.057	2.64	Inf.	4.80	Inf.	29.1	30.9	Inf.	4.84	Inf.	2.66	Inf.	1.86	Inf.	1.46	Inf.	1.23	Inf.	1.07
		200	0.29	1.90	Inf.	2.87	Inf.	5.83	6.19	2714.	2.96	Inf.	1.95	Inf.	1.46	Inf.	1.17	Inf.	0.99	Inf.	0.84
		100	0.57	1.41	215.	1.91	6.41	2.91	3.09	5.75	2.00	48.1	1.46	Inf.	1.15	Inf.	0.95	Inf.	0.80	Inf.	0.67
50	1.1	0.92	2.80	1.14	2.05	1.46	1.55	1.93	1.21	2.64	0.98	3.63	0.81	4.44	0.69	3.93	0.58	2.39	0.482		
30	1.9	0.63	1.20	0.74	1.07	0.87	0.93	1.02	0.80	1.18	0.68	1.29	0.59	1.29	0.51	1.13	0.432	0.84	0.358		
20	2.9	0.446	0.69	0.51	0.67	0.58	0.62	0.65	0.56	0.70	0.499	0.73	0.441	0.70	0.386	0.62	0.333	0.486	0.278		
15	3.8	0.344	0.481	0.390	0.481	0.435	0.462	0.474	0.431	0.50	0.394	0.51	0.355	0.487	0.315	0.433	0.274	0.352	0.231		
10	5.7	0.232	0.293	0.262	0.306	0.288	0.306	0.310	0.296	0.323	0.280	0.324	0.259	0.311	0.235	0.282	0.208	0.239	0.179		
7	8.2	0.160	0.190	0.181	0.205	0.200	0.212	0.214	0.212	0.224	0.206	0.225	0.195	0.219	0.181	0.203	0.164	0.179	0.146		
5	11.5	0.109	0.124	0.125	0.139	0.140	0.148	0.152	0.153	0.160	0.153	0.163	0.149	0.161	0.142	0.154	0.133	0.143	0.123		
4	14.5	0.082	0.092	0.097	0.106	0.109	0.116	0.120	0.122	0.128	0.125	0.133	0.125	0.134	0.122	0.131	0.117	0.125	0.111		
3	19.5	0.055	0.060	0.067	0.072	0.078	0.082	0.088	0.090	0.096	0.096	0.102	0.099	0.106	0.100	0.108	0.100	0.109	0.100		
2	30.0	0.026	0.027	0.035	0.037	0.044	0.046	0.053	0.055	0.061	0.063	0.069	0.069	0.077	0.075	0.084	0.081	0.092	0.088		
1.5	41.8	0.010	0.011	0.017	0.018	0.024	0.026	0.032	0.034	0.041	0.042	0.049	0.050	0.059	0.059	0.069	0.068	0.082	0.080		
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.004	0.004	0.009	0.009	0.016	0.016	0.027	0.028	0.044	0.046		

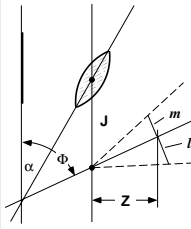


Table gives value of l or m for $Z = 1$.

TABLE XVIa: DEPTH OF FIELD FOR f/64 — by angle

By Angle f-number = 64 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)											
		LENS J/f	TILT α	1	2	5	10	20	30	40	50	60	
Other Combinations: f-number a/f	10000	0.006	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°		
	1000	0.057	0.6° to 3.2°	0.9° to 175.7°	1.1° to 178.2°	1.2° to 178.5°	1.3° to 178.6°	1.3° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°		
	200	0.29	0.9° to 1.1°	1.7° to 2.6°	3.1° to 15.8°	4.3° to 159.9°	5.3° to 170.4°	5.8° to 171.9°	6.2° to 172.5°	6.4° to 172.9°	6.5° to 173.1°		
	100	0.57	1.0° to 1.0°	1.9° to 2.2°	3.9° to 7.2°	6.1° to 30.2°	8.6° to 145.6°	10.0° to 158.7°	10.9° to 162.4°	11.6° to 164.2°	12.2° to 165.4°		
	23	1/500	50	1.1	n/a	2.0° to 2.0°	4.5° to 5.6°	7.8° to 14.3°	12.3° to 52.7°	15.4° to 108.8°	17.7° to 132.9°	19.5° to 142.7°	21.2° to 148.0°
	32	1/750	30	1.9	n/a	2.0° to 2.0°	4.8° to 5.2°	8.8° to 11.8°	14.9° to 31.2°	19.5° to 61.2°	23.3° to 92.1°	26.6° to 112.8°	29.6° to 125.2°
	45	1/1000	20	2.9	n/a	n/a	4.9° to 5.1°	9.3° to 10.8°	16.6° to 25.6°	22.5° to 45.2°	27.6° to 67.8°	32.2° to 88.6°	36.6° to 104.6°
	64	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.6° to 10.5°	17.6° to 23.4°	24.3° to 39.5°	30.3° to 57.8°	35.8° to 76.1°	41.2° to 92.1°
	90	1/2000	10	5.7	n/a	n/a	n/a	9.9° to 10.1°	18.7° to 21.7°	26.4° to 34.9°	33.6° to 49.6°	40.3° to 64.8°	46.8° to 79.4°
	128	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.3° to 20.8°	27.9° to 32.6°	35.8° to 45.5°	43.4° to 58.9°	50.9° to 72.2°
181	1/4000	5	11.5	n/a	n/a	n/a	n/a	19.7° to 20.3°	28.8° to 31.3°	37.5° to 43.0°	45.7° to 55.3°	53.8° to 67.6°	
256	1/6000	4	14.5	n/a	n/a	n/a	n/a	19.9° to 20.1°	29.3° to 30.7°	38.3° to 41.9°	46.9° to 53.6°	55.4° to 65.4°	
362	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.8° to 30.3°	39.1° to 40.9°	48.2° to 52.0°	57.1° to 63.3°	
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	39.9° to 40.1°	49.4° to 50.6°	58.8° to 61.3°	
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	49.9° to 50.1°	59.6° to 60.4°	
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

By Angle f-number = 64 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)									
		LENS J/f	TILT α	70	80	90	100	110	120	130	140
Other Combinations: f-number a/f	10000	0.006	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°
	1000	0.057	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.7°	1.4° to 178.8°
	200	0.29	6.7° to 173.3°	6.8° to 173.5°	7.0° to 173.6°	7.1° to 173.7°	7.3° to 173.9°	7.4° to 174.0°	7.7° to 174.2°	8.0° to 174.4°	8.6° to 174.7°
	100	0.57	12.7° to 166.2°	13.2° to 166.8°	13.7° to 167.4°	14.3° to 167.9°	14.9° to 168.4°	15.7° to 168.9°	16.8° to 169.5°	18.5° to 170.1°	21.8° to 171.0°
	50	1.1	22.8° to 151.4°	24.4° to 153.8°	26.1° to 155.8°	28.0° to 157.5°	30.3° to 159.1°	33.4° to 160.7°	38.1° to 162.4°	46.5° to 164.2°	65.6° to 166.4°
	30	1.9	32.6° to 133.2°	35.8° to 138.8°	39.2° to 143.2°	43.2° to 146.8°	48.3° to 150.0°	55.2° to 153.0°	65.5° to 156.1°	82.5° to 159.2°	110.0° to 162.8°
	20	2.9	41.0° to 116.2°	45.6° to 124.9°	50.8° to 131.6°	56.8° to 137.2°	64.3° to 142.1°	74.0° to 146.7°	87.4° to 151.0°	105.5° to 155.5°	127.6° to 160.3°
	15	3.8	46.6° to 105.0°	52.3° to 115.3°	58.6° to 123.6°	65.8° to 130.6°	74.5° to 136.7°	85.4° to 142.4°	99.0° to 147.7°	115.7° to 153.1°	134.3° to 158.7°
	10	5.7	53.5° to 92.6°	60.4° to 104.0°	67.9° to 113.8°	76.3° to 122.4°	86.0° to 130.0°	97.1° to 137.0°	110.0° to 143.7°	124.5° to 150.2°	139.7° to 156.9°
	7	8.2	58.3° to 84.8°	66.1° to 96.5°	74.3° to 107.0°	83.2° to 116.5°	93.1° to 125.1°	104.0° to 133.1°	116.0° to 140.8°	129.0° to 148.2°	142.4° to 155.7°
5	11.5	61.9° to 79.7°	70.2° to 91.3°	78.9° to 102.1°	88.0° to 112.1°	97.8° to 121.4°	108.4° to 130.2°	119.7° to 138.6°	131.7° to 146.8°	144.0° to 154.8°	
4	14.5	63.9° to 77.2°	72.4° to 88.6°	81.3° to 99.5°	90.5° to 109.8°	100.2° to 119.4°	110.6° to 128.6°	121.5° to 137.4°	133.0° to 146.0°	144.8° to 154.4°	
3	19.5	65.9° to 74.7°	74.7° to 85.9°	83.8° to 96.8°	93.0° to 107.2°	102.7° to 117.3°	112.8° to 126.9°	123.3° to 136.1°	134.3° to 145.1°	145.5° to 154.0°	
2	30.0	68.1° to 72.1°	77.2° to 83.0°	86.5° to 93.8°	95.8° to 104.4°	105.3° to 114.8°	115.1° to 124.9°	125.2° to 134.7°	135.6° to 144.2°	146.2° to 153.5°	
1.5	41.8	69.2° to 70.8°	78.6° to 81.4°	88.0° to 92.1°	97.4° to 102.7°	106.9° to 113.2°	116.5° to 123.6°	126.3° to 133.7°	136.4° to 143.6°	146.6° to 153.2°	
1	90.0	n/a	n/a	n/a	n/a	99.9° to 100.1°	109.7° to 110.3°	119.4° to 120.6°	129.0° to 131.0°	138.6° to 141.5°	148.2° to 151.9°

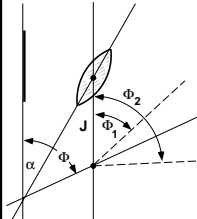


Table gives range from Φ₁ to Φ₂

TABLE XVib: DEPTH OF FIELD FOR f/64 — by depth of field fraction

Fractions f-number = 64 a/f = 1/1500		LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
Other combinations: f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
				10000	0.006	0.88	Inf.	0.93	Inf.	0.98	Inf.	1.00	Inf.	1.06	Inf.	1.15	Inf.	1.30	Inf.	1.55	Inf.
		1000	0.057	0.389	2.22	0.57	Inf.	0.78	Inf.	0.89	Inf.	0.99	Inf.	1.09	Inf.	1.24	Inf.	1.48	Inf.	1.89	Inf.
		200	0.29	0.069	0.085	0.174	0.293	0.389	2.20	0.58	Inf.	0.77	Inf.	0.90	Inf.	1.04	Inf.	1.24	Inf.	1.56	Inf.
		100	0.57	0.013	0.014	0.069	0.085	0.220	0.434	0.390	2.12	0.59	Inf.	0.73	Inf.	0.87	Inf.	1.03	Inf.	1.27	Inf.
23	1/500	50	1.1	n/a	n/a	0.013	0.014	0.097	0.129	0.220	0.431	0.394	1.87	0.52	10.11	0.64	Inf.	0.77	Inf.	0.93	32.4
32	1/750	30	1.9	n/a	n/a	0.000	0.000	0.040	0.046	0.124	0.178	0.262	0.58	0.371	1.21	0.467	2.00	0.57	2.54	0.68	2.50
45	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.013	0.014	0.069	0.085	0.175	0.285	0.264	0.54	0.343	0.82	0.420	1.04	0.50	1.14
64	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.003	0.003	0.040	0.046	0.124	0.175	0.199	0.334	0.266	0.499	0.330	0.64	0.394	0.72
90	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.013	0.014	0.069	0.084	0.124	0.171	0.176	0.262	0.224	0.345	0.270	0.407
128	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.034	0.039	0.075	0.114	0.092	0.151	0.149	0.203	0.186	0.249
181	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.013	0.014	0.040	0.046	0.069	0.083	0.098	0.120	0.125	0.154
256	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.005	0.005	0.023	0.026	0.046	0.053	0.070	0.082	0.092	0.110
362	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.008	0.009	0.024	0.026	0.041	0.046	0.059	0.067
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.004	0.004	0.013	0.013	0.024	0.026
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.007	0.007
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT J/f α		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
		70		80		90		100		110		120		130		140		150	
f-number	a/f	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
		10000	0.006	2.90	Inf.	5.68	Inf.	409.	446.	Inf.	5.68	Inf.	2.90	Inf.	1.99	1.55	Inf.	1.30	Inf.
1000	0.057	2.72	Inf.	5.04	Inf.	40.9	44.6	Inf.	5.09	Inf.	2.73	Inf.	1.90	1.49	Inf.	1.25	Inf.	1.10	
200	0.29	2.12	Inf.	3.36	Inf.	8.18	8.91	Inf.	3.48	Inf.	2.17	Inf.	1.59	1.27	Inf.	1.07	Inf.	0.92	
100	0.57	1.66	Inf.	2.37	18.17	4.09	4.46	13.57	2.50	Inf.	1.73	Inf.	1.32	1.07	Inf.	0.90	Inf.	0.77	
50	1.1	1.15	7.00	1.48	3.50	2.05	2.23	3.13	1.60	5.85	1.23	19.22	0.99	Inf.	0.83	Inf.	0.70	20.5	0.59
30	1.9	0.81	2.11	0.99	1.68	1.23	1.34	1.55	1.08	1.98	0.89	2.46	0.75	2.73	0.64	2.44	0.54	1.68	0.454
20	2.9	0.59	1.11	0.69	1.01	0.82	0.89	0.95	0.77	1.09	0.67	1.19	0.58	1.20	0.50	1.07	0.431	0.82	0.362
15	3.8	0.461	0.75	0.53	0.72	0.61	0.67	0.69	0.60	0.76	0.54	0.80	0.475	0.78	0.417	0.70	0.362	0.56	0.306
10	5.7	0.316	0.442	0.361	0.452	0.405	0.441	0.445	0.418	0.475	0.387	0.487	0.353	0.475	0.317	0.433	0.281	0.365	0.242
7	8.2	0.219	0.282	0.251	0.300	0.281	0.305	0.306	0.300	0.324	0.287	0.331	0.270	0.325	0.248	0.303	0.225	0.267	0.200
5	11.5	0.151	0.182	0.175	0.202	0.197	0.214	0.215	0.218	0.229	0.215	0.237	0.208	0.236	0.198	0.227	0.184	0.210	0.170
4	14.5	0.114	0.134	0.135	0.153	0.154	0.167	0.170	0.175	0.183	0.177	0.191	0.175	0.194	0.170	0.191	0.163	0.183	0.154
3	19.5	0.076	0.087	0.093	0.104	0.109	0.119	0.124	0.129	0.136	0.136	0.146	0.140	0.153	0.141	0.157	0.140	0.158	0.139
2	30.0	0.036	0.039	0.049	0.053	0.062	0.066	0.074	0.079	0.087	0.089	0.099	0.099	0.110	0.106	0.121	0.114	0.133	0.123
1.5	41.8	0.015	0.016	0.024	0.026	0.034	0.037	0.046	0.048	0.057	0.060	0.070	0.072	0.083	0.084	0.098	0.097	0.118	0.113
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.001	0.005	0.005	0.012	0.013	0.023	0.024	0.038	0.040	0.063	0.065

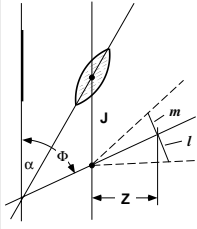


Table gives value of l or m for $Z = 1$.

TABLE XVIIa: DEPTH OF FIELD FOR f/90 — by angle

By Angle f-number = 90 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)										
		LENS J/f	TILT α	1	2	5	10	20	30	40	50	60
Other Combinations: f-number a/f	10000	0.006	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	
	1000	0.057	0.5° to 52.4°	0.7° to 178.2°	0.9° to 178.9°	0.9° to 179.0°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	
	200	0.29	0.9° to 1.1°	1.5° to 3.0°	2.7° to 83.0°	3.5° to 171.1°	4.2° to 174.1°	4.4° to 174.7°	4.6° to 175.0°	4.7° to 175.2°	4.8° to 175.3°	
	100	0.57	1.0° to 1.0°	1.8° to 2.3°	3.6° to 8.8°	5.3° to 89.3°	7.0° to 163.0°	7.9° to 167.3°	8.5° to 168.8°	8.9° to 169.6°	9.2° to 170.1°	
	32	1/500	50	1.1	n/a	2.0° to 2.0°	4.4° to 6.0°	7.2° to 17.4°	10.7° to 95.2°	12.9° to 141.0°	14.4° to 151.5°	15.6° to 156.0°
	45	1/750	30	1.9	n/a	2.0° to 2.0°	4.7° to 5.3°	8.4° to 12.7°	13.5° to 40.3°	17.1° to 87.7°	19.9° to 119.6°	22.3° to 134.0°
	64	1/1000	20	2.9	n/a	n/a	4.9° to 5.1°	9.1° to 11.2°	15.5° to 28.9°	20.5° to 55.9°	24.5° to 86.0°	28.0° to 108.1°
	90	1/1500	15	3.8	n/a	n/a	5.0° to 5.0°	9.5° to 10.7°	16.8° to 25.3°	22.6° to 45.2°	27.6° to 68.8°	32.1° to 90.4°
	127	1/2000	10	5.7	n/a	n/a	n/a	9.8° to 10.2°	18.2° to 22.4°	25.3° to 37.4°	31.5° to 54.8°	37.3° to 72.7°
	180	1/3000	7	8.2	n/a	n/a	n/a	10.0° to 10.0°	19.1° to 21.1°	27.1° to 33.9°	34.4° to 48.2°	41.2° to 63.3°
255	1/4000	5	11.5	n/a	n/a	n/a	n/a	19.6° to 20.4°	28.4° to 31.9°	36.5° to 44.5°	44.2° to 57.7°	
360	1/6000	4	14.5	n/a	n/a	n/a	n/a	19.9° to 20.1°	29.1° to 31.0°	37.7° to 42.8°	45.8° to 55.2°	
509	1/8500	3	19.5	n/a	n/a	n/a	n/a	20.0° to 20.0°	29.7° to 30.4°	38.8° to 41.3°	47.5° to 52.9°	
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	39.8° to 40.2°	49.2° to 50.8°	
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	49.9° to 50.1°	
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

By Angle f-number = 90 a/f = 1/1500		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)									
		LENS J/f	TILT α	70	80	90	100	110	120	130	140
Other Combinations: f-number a/f	10000	0.006	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°	0.1° to 179.9°
	1000	0.057	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°	1.0° to 179.1°
	200	0.29	4.9° to 175.4°	5.0° to 175.5°	5.0° to 175.5°	5.1° to 175.6°	5.2° to 175.7°	5.3° to 175.7°	5.4° to 175.8°	5.4° to 175.8°	5.6° to 175.9°
	100	0.57	9.5° to 170.5°	9.8° to 170.8°	10.0° to 171.1°	10.3° to 171.4°	10.6° to 171.6°	11.0° to 171.9°	11.5° to 172.2°	12.3° to 172.6°	13.6° to 173.2°
	50	1.1	17.6° to 160.2°	18.5° to 161.5°	19.5° to 162.6°	20.5° to 163.6°	21.8° to 164.5°	23.4° to 165.4°	25.6° to 166.4°	29.5° to 167.6°	37.8° to 169.0°
	30	1.9	26.3° to 146.3°	28.4° to 149.7°	30.5° to 152.4°	33.0° to 154.7°	36.1° to 156.7°	40.2° to 158.7°	46.5° to 160.8°	57.5° to 163.0°	80.9° to 165.5°
	20	2.9	34.5° to 130.8°	37.9° to 137.0°	41.5° to 141.9°	45.8° to 145.8°	51.1° to 149.3°	58.4° to 152.6°	69.0° to 155.8°	85.9° to 159.2°	112.0° to 162.9°
	15	3.8	40.5° to 118.5°	44.9° to 127.0°	49.8° to 133.6°	55.5° to 139.1°	62.4° to 143.8°	71.6° to 148.1°	84.2° to 152.3°	101.9° to 156.6°	124.5° to 161.1°
	10	5.7	48.5° to 102.5°	54.3° to 113.4°	60.7° to 122.3°	68.0° to 129.7°	76.7° to 136.2°	87.2° to 142.2°	100.4° to 147.8°	116.3° to 153.3°	134.0° to 159.1°
	7	8.2	54.5° to 91.6°	61.4° to 103.4°	68.8° to 113.6°	77.0° to 122.5°	86.3° to 130.4°	97.1° to 137.6°	109.5° to 144.3°	123.6° to 150.9°	138.6° to 157.6°
5	11.5	59.1° to 84.1°	66.8° to 96.1°	74.8° to 107.0°	83.4° to 116.8°	92.9° to 125.7°	103.5° to 133.9°	115.1° to 141.6°	127.8° to 149.1°	141.2° to 156.5°	
4	14.5	61.7° to 80.4°	69.7° to 92.3°	78.0° to 103.4°	86.8° to 113.7°	96.3° to 123.1°	106.6° to 131.9°	117.8° to 140.1°	129.8° to 148.1°	142.4° to 156.0°	
3	19.5	64.4° to 76.7°	72.8° to 88.4°	81.4° to 99.6°	90.3° to 110.2°	99.8° to 120.2°	109.8° to 129.6°	120.5° to 138.5°	131.8° to 147.1°	143.5° to 155.5°	
2	30.0	67.3° to 73.0°	76.2° to 84.3°	85.1° to 95.4°	94.2° to 106.3°	103.5° to 116.8°	113.2° to 126.8°	123.2° to 136.5°	133.7° to 145.8°	144.6° to 154.9°	
1.5	41.8	68.9° to 71.2°	78.1° to 82.1°	87.3° to 93.0°	96.4° to 103.9°	105.7° to 114.6°	115.2° to 125.0°	124.9° to 135.2°	134.9° to 145.0°	145.2° to 154.5°	
1	90.0	n/a	n/a	n/a	99.9° to 100.1°	109.6° to 110.4°	119.2° to 120.9°	128.6° to 131.5°	138.0° to 142.1°	147.5° to 152.6°	

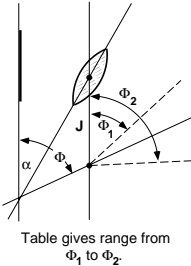


Table gives range from Φ_1 to Φ_2

TABLE XVIIb: DEPTH OF FIELD FOR f/90 — by depth of field fraction

Fractions f-number = 90 a/f = 1/1500		LENS TILT		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
				1		2		5		10		20		30		40		50		60	
f-number	a/f	J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l		
Other combinations:	10000	0.006	0.91	Inf.	0.95	Inf.	0.98	Inf.	1.01	Inf.	1.06	Inf.	1.15	Inf.	1.30	Inf.	1.55	Inf.	1.99	Inf.	
	1000	0.057	0.468	71.7	0.65	Inf.	0.83	Inf.	0.92	Inf.	1.01	Inf.	1.11	Inf.	1.26	Inf.	1.50	Inf.	1.92	Inf.	
	200	0.29	0.093	0.125	0.226	0.479	0.469	53.9	0.66	Inf.	0.83	Inf.	0.96	Inf.	1.10	Inf.	1.32	Inf.	1.66	Inf.	
	100	0.57	0.018	0.020	0.093	0.125	0.281	0.76	0.471	30.4	0.67	Inf.	0.81	Inf.	0.95	Inf.	1.14	Inf.	1.42	Inf.	
32	1/500	50	1.1	n/a	n/a	0.018	0.020	0.129	0.195	0.281	0.75	0.478	11.10	0.62	Inf.	0.74	Inf.	0.89	Inf.	1.09	Inf.
45	1/750	30	1.9	n/a	n/a	0.000	0.000	0.055	0.066	0.164	0.274	0.331	1.08	0.457	3.16	0.57	8.45	0.69	12.37	0.83	7.79
64	1/1000	20	2.9	n/a	n/a	n/a	n/a	0.018	0.020	0.093	0.125	0.228	0.460	0.336	0.97	0.431	1.61	0.53	2.10	0.63	2.16
90	1/1500	15	3.8	n/a	n/a	n/a	n/a	0.004	0.004	0.055	0.066	0.165	0.269	0.258	0.54	0.341	0.85	0.422	1.11	0.51	1.23
127	1/2000	10	5.7	n/a	n/a	n/a	n/a	n/a	n/a	0.018	0.020	0.093	0.124	0.165	0.261	0.231	0.410	0.293	0.54	0.355	0.64
180	1/3000	7	8.2	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.047	0.056	0.101	0.135	0.153	0.223	0.201	0.308	0.249	0.376
255	1/4000	5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.018	0.020	0.055	0.066	0.094	0.121	0.132	0.177	0.169	0.228
360	1/6000	4	14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.006	0.007	0.032	0.037	0.063	0.076	0.095	0.119	0.126	0.160
509	1/8500	3	19.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.000	0.000	0.012	0.012	0.033	0.037	0.056	0.066	0.081	0.096
		2	30.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.006	0.006	0.018	0.019	0.033	0.037
		1.5	41.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.010	0.010
		1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LENS TILT		PLANE OF SHARP FOCUS TILT (Φ - DEGREES)																	
		70		80		90		100		110		120		130		140		150	
J/f	α	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
10000	0.006	2.91	Inf.	5.70	Inf.	566.	638.	Inf.	5.71	Inf.	2.91	Inf.	1.99	Inf.	1.55	Inf.	1.30	Inf.	1.15
1000	0.057	2.77	Inf.	5.22	Inf.	56.6	63.8	Inf.	5.28	Inf.	2.79	Inf.	1.93	Inf.	1.51	Inf.	1.27	Inf.	1.11
200	0.29	2.29	Inf.	3.80	Inf.	11.32	12.77	Inf.	3.95	Inf.	2.35	Inf.	1.70	Inf.	1.34	Inf.	1.13	Inf.	0.98
100	0.57	1.88	Inf.	2.83	Inf.	5.66	6.38	194.2	3.01	Inf.	1.97	Inf.	1.47	Inf.	1.19	Inf.	1.00	Inf.	0.86
50	1.1	1.38	Inf.	1.87	6.80	2.83	3.19	5.47	2.04	34.6	1.49	Inf.	1.17	Inf.	0.96	Inf.	0.81	Inf.	0.69
30	1.9	1.02	4.38	1.28	2.75	1.70	1.91	2.39	1.43	3.69	1.13	6.41	0.93	11.55	0.78	11.87	0.66	5.23	0.56
20	2.9	0.76	1.90	0.92	1.57	1.13	1.27	1.41	1.05	1.76	0.87	2.14	0.74	2.36	0.63	2.15	0.54	1.56	0.457
15	3.8	0.60	1.20	0.71	1.09	0.85	0.95	1.00	0.82	1.16	0.71	1.30	0.62	1.34	0.54	1.22	0.463	0.96	0.394
10	5.7	0.420	0.68	0.488	0.67	0.56	0.63	0.63	0.58	0.70	0.52	0.74	0.470	0.74	0.418	0.68	0.368	0.57	0.319
7	8.2	0.295	0.421	0.342	0.440	0.388	0.437	0.432	0.421	0.468	0.395	0.489	0.365	0.488	0.333	0.459	0.301	0.404	0.267
5	11.5	0.205	0.268	0.239	0.294	0.272	0.306	0.302	0.307	0.327	0.299	0.343	0.286	0.346	0.269	0.335	0.250	0.310	0.230
4	14.5	0.156	0.195	0.185	0.222	0.213	0.239	0.238	0.247	0.259	0.247	0.274	0.242	0.281	0.233	0.279	0.222	0.268	0.210
3	19.5	0.105	0.125	0.129	0.150	0.151	0.170	0.173	0.183	0.192	0.191	0.208	0.195	0.219	0.195	0.226	0.193	0.228	0.191
2	30.0	0.050	0.056	0.068	0.076	0.086	0.095	0.104	0.112	0.121	0.126	0.139	0.139	0.155	0.149	0.171	0.159	0.190	0.171
1.5	41.8	0.021	0.022	0.033	0.037	0.048	0.052	0.063	0.069	0.080	0.085	0.098	0.101	0.117	0.118	0.139	0.135	0.167	0.158
1	90.0	n/a	n/a	n/a	n/a	n/a	n/a	0.002	0.002	0.007	0.008	0.017	0.018	0.031	0.033	0.053	0.056	0.088	0.092

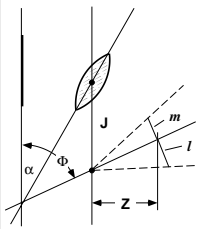


Table gives value of l or m for $Z = 1$.

TABLE XVIIIa: LENS-TO-PLANE OF SHARP FOCUS DISTANCE, D—in meters

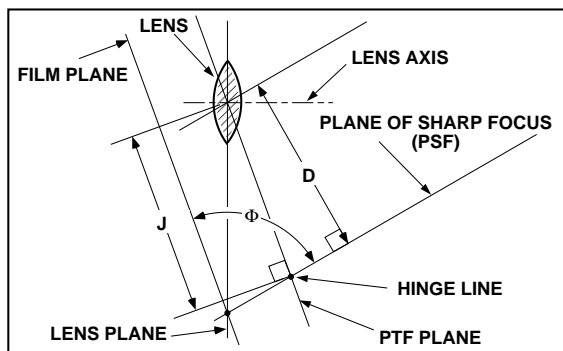
Distance J (in meters)	PLANE OF SHARP FOCUS TILT (Φ - Degrees)																	
	1	2	5	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
0.1	0.002 m	0.003 m	0.009 m	0.02 m	0.03 m	0.05 m	0.06 m	0.08 m	0.09 m	0.09 m	0.10 m	0.10 m	0.10 m	0.09 m	0.09 m	0.08 m	0.06 m	0.05 m
0.2	0.003 m	0.007 m	0.017 m	0.03 m	0.07 m	0.10 m	0.13 m	0.15 m	0.17 m	0.19 m	0.20 m	0.20 m	0.20 m	0.19 m	0.17 m	0.15 m	0.13 m	0.10 m
0.3	0.005 m	0.010 m	0.026 m	0.05 m	0.10 m	0.15 m	0.19 m	0.23 m	0.26 m	0.28 m	0.30 m	0.30 m	0.30 m	0.28 m	0.26 m	0.23 m	0.19 m	0.15 m
0.4	0.007 m	0.014 m	0.035 m	0.07 m	0.14 m	0.20 m	0.26 m	0.31 m	0.35 m	0.38 m	0.39 m	0.40 m	0.39 m	0.38 m	0.35 m	0.31 m	0.26 m	0.20 m
0.5	0.009 m	0.017 m	0.04 m	0.09 m	0.17 m	0.25 m	0.32 m	0.38 m	0.43 m	0.47 m	0.49 m	0.50 m	0.49 m	0.47 m	0.43 m	0.38 m	0.32 m	0.25 m
0.75	0.013 m	0.026 m	0.07 m	0.13 m	0.26 m	0.38 m	0.48 m	0.57 m	0.65 m	0.70 m	0.74 m	0.75 m	0.74 m	0.70 m	0.65 m	0.57 m	0.48 m	0.38 m
1	0.017 m	0.03 m	0.09 m	0.17 m	0.34 m	0.50 m	0.64 m	0.77 m	0.87 m	0.94 m	0.98 m	1.00 m	0.98 m	0.94 m	0.87 m	0.77 m	0.64 m	0.50 m
1.5	0.026 m	0.05 m	0.13 m	0.26 m	0.51 m	0.75 m	0.96 m	1.15 m	1.30 m	1.41 m	1.48 m	1.50 m	1.48 m	1.41 m	1.30 m	1.15 m	0.96 m	0.75 m
2	0.035 m	0.07 m	0.17 m	0.35 m	0.68 m	1.00 m	1.29 m	1.53 m	1.73 m	1.88 m	1.97 m	2.00 m	1.97 m	1.88 m	1.73 m	1.53 m	1.29 m	1.00 m
2.5	0.04 m	0.09 m	0.22 m	0.43 m	0.86 m	1.25 m	1.61 m	1.92 m	2.17 m	2.35 m	2.46 m	2.50 m	2.46 m	2.35 m	2.17 m	1.92 m	1.61 m	1.25 m
3	0.05 m	0.10 m	0.26 m	0.52 m	1.03 m	1.50 m	1.93 m	2.30 m	2.60 m	2.82 m	2.95 m	3.00 m	2.95 m	2.82 m	2.60 m	2.30 m	1.93 m	1.50 m
4	0.07 m	0.14 m	0.35 m	0.69 m	1.37 m	2.00 m	2.57 m	3.06 m	3.46 m	3.76 m	3.94 m	4.00 m	3.94 m	3.76 m	3.46 m	3.06 m	2.57 m	2.00 m
5	0.09 m	0.17 m	0.44 m	0.87 m	1.71 m	2.50 m	3.21 m	3.83 m	4.33 m	4.70 m	4.92 m	5.00 m	4.92 m	4.70 m	4.33 m	3.83 m	3.21 m	2.50 m
6	0.10 m	0.21 m	0.52 m	1.04 m	2.05 m	3.00 m	3.86 m	4.60 m	5.20 m	5.64 m	5.91 m	6.00 m	5.91 m	5.64 m	5.20 m	4.60 m	3.86 m	3.00 m
7	0.12 m	0.24 m	0.61 m	1.22 m	2.39 m	3.50 m	4.50 m	5.36 m	6.06 m	6.58 m	6.89 m	7.00 m	6.89 m	6.58 m	6.06 m	5.36 m	4.50 m	3.50 m
8	0.14 m	0.28 m	0.70 m	1.39 m	2.74 m	4.00 m	5.14 m	6.13 m	6.93 m	7.52 m	7.88 m	8.00 m	7.88 m	7.52 m	6.93 m	6.13 m	5.14 m	4.00 m
9	0.16 m	0.31 m	0.78 m	1.56 m	3.08 m	4.50 m	5.79 m	6.89 m	7.79 m	8.46 m	8.86 m	9.00 m	8.86 m	8.46 m	7.79 m	6.89 m	5.79 m	4.50 m
10	0.17 m	0.35 m	0.87 m	1.74 m	3.42 m	5.00 m	6.43 m	7.66 m	8.66 m	9.40 m	9.85 m	10.00 m	9.85 m	9.40 m	8.66 m	7.66 m	6.43 m	5.00 m
12	0.21 m	0.42 m	1.05 m	2.08 m	4.10 m	6.00 m	7.71 m	9.19 m	10.39 m	11.28 m	11.82 m	12.00 m	11.82 m	11.28 m	10.39 m	9.19 m	7.71 m	6.00 m
15	0.26 m	0.52 m	1.31 m	2.60 m	5.13 m	7.50 m	9.64 m	11.49 m	12.99 m	14.10 m	14.77 m	15.00 m	14.77 m	14.10 m	12.99 m	11.49 m	9.64 m	7.50 m
20	0.35 m	0.70 m	1.74 m	3.47 m	6.84 m	10.00 m	12.86 m	15.32 m	17.32 m	18.79 m	19.70 m	20.00 m	19.70 m	18.79 m	17.32 m	15.32 m	12.86 m	10.00 m
25	0.44 m	0.87 m	2.18 m	4.34 m	8.55 m	12.50 m	16.07 m	19.15 m	21.65 m	23.49 m	24.62 m	25.00 m	24.62 m	23.49 m	21.65 m	19.15 m	16.07 m	12.50 m
30	0.52 m	1.05 m	2.61 m	5.21 m	10.26 m	15.00 m	19.28 m	22.98 m	25.98 m	28.19 m	29.54 m	30.00 m	29.54 m	28.19 m	25.98 m	22.98 m	19.28 m	15.00 m
50	0.87 m	1.74 m	4.36 m	8.68 m	17.10 m	25.00 m	32.14 m	38.30 m	43.30 m	46.98 m	49.24 m	50.00 m	49.24 m	46.98 m	43.30 m	38.30 m	32.14 m	25.00 m

It is often required that we know the distance from the lens to the Plane of Sharp Focus, measured in a direction perpendicular to the Plane of Sharp Focus. This is especially the case when we wish to use the 'Object Field Method' for determining depth of field. These two tables let you determine that distance, **D**, from the lens-to-hinge line distance, **J**, and the Plane of Sharp Focus tilt, Φ .

Example: In the main example described in Chapter 5, we used a distance, **J**, of 8 feet, and a Plane of Sharp Focus tilt of 80°. Using Table XVIIIb, looking along the row for 8 ft. and under the column for 80°, we find **D** = 7 ft. 10.5 in., almost the same as **J**. (**D** and **J** are about equal only when Φ is close to 90°.)

TABLE XVIIIb: LENS-TO-PLANE OF SHARP FOCUS DISTANCE, D—in feet

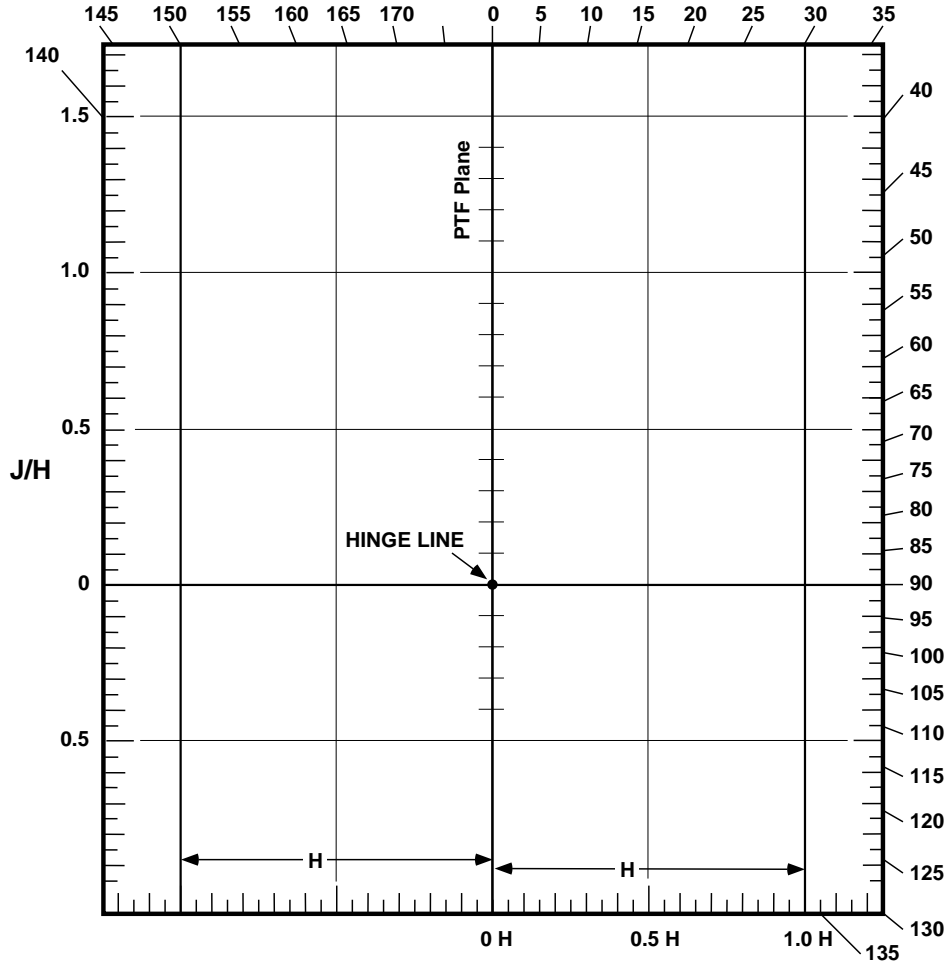
Distance J (in feet)	PLANE OF SHARP FOCUS TILT (Φ - Degrees)																	
	1	2	5	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
0.25 (3")	0.05"	0.10"	0.26"	0.52"	1.0"	1.5"	1.9"	2.3"	2.6"	2.8"	3.0"	0' 3."	3.0"	2.8"	2.6"	2.3"	1.9"	1.5"
0.5 (6")	0.10"	0.21"	0.52"	1.0"	2.1"	3.0"	3.9"	4.6"	5.2"	5.6"	5.9"	0' 6."	5.9"	5.6"	5.2"	4.6"	3.9"	3.0"
0.75 (9")	0.16"	0.31"	0.78"	1.6"	3.1"	4.5"	5.8"	6.9"	7.8"	8.5"	8.9"	0' 9."	8.9"	8.5"	7.8"	6.9"	5.8"	4.5"
1	0.21"	0.42"	1.0"	2.1"	4.1"	6.0"		9.2"	10.4"	11.3"	11.8"	1' 0."	11.8"	11.3"	10.4"	9.2"	7.7"	6.0"
1.25 (15")	0.26"	0.52"	1.3"	2.6"	5.1"	7.5"	0' 9.6"	11.5"	1' 1.0"	1' 2.1"	1' 2.8"	1' 3."	1' 2.8"	1' 2.1"	1' 1.0"	11.5"	9.6"	7.5"
1.5 (18")	0.31"	0.63"	1.6"	3.1"	6.2"	9."	11.6"	1' 1.8"	1' 3.6"	1' 4.9"	1' 5.7"	1' 6."	1' 5.7"	1' 4.9"	1' 3.6"	11.6"	9."	9."
2	0.42"	0.84"	2.1"	4.2"	8.2"	1' 0."	1' 3.4"	1' 6.4"	1' 8.8"	1' 10.6"	1' 11.6"	2' 0."	1' 11.6"	1' 10.6"	1' 8.8"	1' 6.4"	1' 3.4"	1' 0."
2.5 (30")	0.52"	1.0"	2.6"	5.2"	10.3"	1' 3."	1' 7.3"	1' 11.0"	2' 2.0"	2' 4.2"	2' 5.5"	2' 6."	2' 5.5"	2' 4.2"	2' 2.0"	1' 11.0"	1' 7.3"	1' 3."
3	0.63"	1.3"	3.1"	6.3"	1' 0.3"	1' 6."	1' 11.1"	2' 3.6"	2' 7.2"	2' 9.8"	2' 11.5"	3' 0."	2' 11.5"	2' 9.8"	2' 7.2"	2' 3.6"	1' 11.1"	1' 6."
4	0.84"	1.7"	4.2"	8.3"	1' 4.4"	2' 0."	2' 6.9"	3' 0.8"	3' 5.6"	3' 9.1"	3' 11.3"	4' 0."	3' 11.3"	3' 9.1"	3' 5.6"	3' 0.8"	2' 6.9"	2' 0."
5	1.0"	2.1"	5.2"	10.4"	1' 8.5"	2' 6."	3' 2.6"	3' 10.0"	4' 4.0"	4' 8.4"	4' 11.1"	5' 0."	4' 11.1"	4' 8.4"	4' 4.0"	3' 10.0"	3' 2.6"	2' 6."
6	1.3"	2.5"	6.3"	1' 0.5"	2' 0.6"	3' 0."	3' 10.3"	4' 7.2"	5' 2.4"	5' 7.7"	5' 10.9"	6' 0."	5' 10.9"	5' 7.7"	5' 2.4"	4' 7.2"	3' 10.3"	3' 0."
7	1.5"	2.9"	7.3"	1' 2.6"	2' 4.7"	3' 6."	4' 6.0"	5' 4.3"	6' 0.7"	6' 6.9"	6' 10.7"	7' 0."	6' 10.7"	6' 6.9"	6' 0.7"	5' 4.3"	4' 6.0"	3' 6."
8	1.7"	3.4"	8.4"	1' 4.7"	2' 8.8"	4' 0."	5' 1.7"	6' 1.5"	6' 11.1"	7' 6.2"	7' 10.5"	8' 0."	7' 10.5"	7' 6.2"	6' 11.1"	6' 1.5"	5' 1.7"	4' 0."
9	1.9"	3.8"	9.4"	1' 6.8"	3' 0.9"	4' 6."	5' 9.4"	6' 10.7"	7' 9.5"	8' 5.5"	8' 10.4"	9' 0."	8' 10.4"	8' 5.5"	7' 9.5"	6' 10.7"	5' 9.4"	4' 6."
10	2.1"	4.2"	10.5"	1' 8.8"	3' 5.0"	5' 0."	6' 5.1"	7' 7.9"	8' 7.9"	9' 4.8"	9' 10.2"	10' 0."	9' 10.2"	9' 4.8"	8' 7.9"	7' 7.9"	6' 5.1"	5' 0."
12	2.5"	5.0"	1' 0.6"	2' 1.0"	4' 1.3"	6' 0."	7' 8.6"	9' 2.3"	10' 4.7"	11' 3.3"	11' 9.8"	12' 0."	11' 9.8"	11' 3.3"	10' 4.7"	9' 2.3"	7' 8.6"	6' 0."
15	3.1"	6.3"	1' 3.7"	2' 7.3"	5' 1.6"	7' 6."	9' 7.7"	11' 5.9"	12' 11.9"	14' 1.1"	14' 9.3"	15' 0."	14' 9.3"	14' 1.1"	12' 11.9"	11' 5.9"	9' 7.7"	7' 6."
20	4.2"	8.4"	1' 8.9"	3' 5.7"	6' 10.1"	10' 0."	12' 10.3"	15' 3.9"	17' 3.8"	18' 9.5"	19' 8.4"	20' 0."	19' 8.4"	18' 9.5"	17' 3.8"	15' 3.9"	12' 10.3"	10' 0."
30	6.3"	1' 0.6"	2' 7.4"	5' 2.5"	10' 3.1"	15' 0."	19' 3.4"	22' 11.8"	25' 12."	28' 2."	29' 7."	30' 0."	29' 7."	28' 2."	25' 12."	22' 11.8"	19' 3.4"	15' 0."
50	10.5"	1' 8.9"	4' 4.3"	8' 8.2"	17' 1.2"	25' 0."	32' 2."	38' 4."	43' 4."	46' 11.8"	49' 3."	50' 0."	49' 3."	46' 12."	43' 4."	38' 4."	32' 2."	25' 0."
75	1' 3.7"	2' 7.4"	6' 6.4"	13' 0.3"	25' 8."	37' 6."	48' 3."	57' 5."	64' 11."	70' 6."	73' 10."	75' 0."	73' 10."	70' 6."	64' 11."	57' 5."	48' 3."	37' 6."
100	1' 8.9"	3' 5.9"	8' 8.6"	17' 4.4"	34' 2."	50' 0."	64' 3."	76' 7."	86' 7."	93' 12."	98' 6."	100' 0."	98' 6."	93' 12."	86' 7."	76' 7."	64' 3."	50' 0."
200	3' 5.9"	6' 11.8"	17' 5.2"	34' 9."	68' 5."	100' 0."	128' 7."	153' 3."	173' 2."	187' 11."	196' 11.5"	200' 0."	196' 11.5"	187' 11."	173' 2."	153' 3."	128' 7."	100' 0."



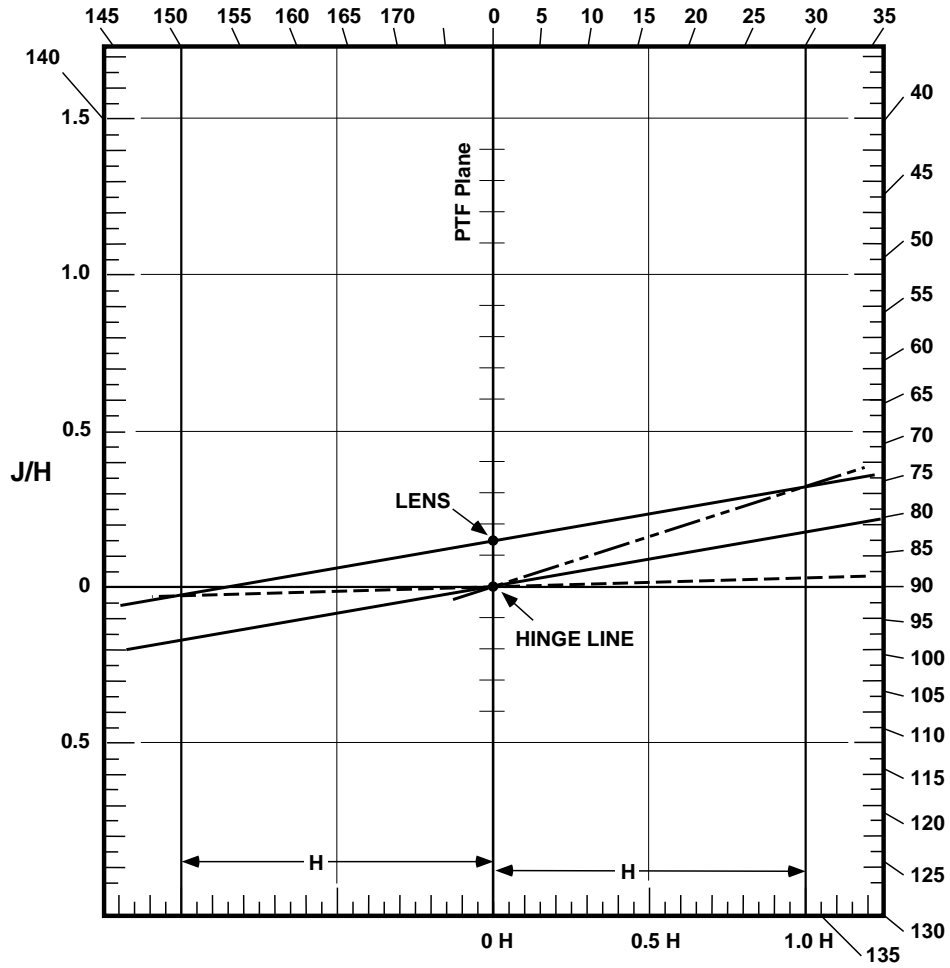
D

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This form of the blank graph starts with the position of the hinge line shown. The lens position must be marked the required distance J from the hinge line, probably above it. Next, a line is drawn at the appropriate angle through the hinge line, representing the plane of sharp focus. It is then necessary to draw a parallel line through the lens position. As before, the limits of depth of field can now be drawn, following the example in Chapter 8. With this form of the graph, the angles of these limits can be read directly; there is no need to draw further parallel lines. The example of Chapter 8 is redrawn on this form on the next page.



feet

LENS TILT REQUIRED FOR DISTANCE J AND FOCAL LENGTH INDICATED

Distance J (in feet)	FOCAL LENGTH (in mm)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.25 (3")	44.07°	58.54°	79.82°	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
0.5 (6")	20.35°	25.25°	29.48°	36.20°	41.01°	43.55°	48.99°	51.94°	62.35°	79.82°	n/a	n/a	n/a	n/a	n/a
0.75 (9")	13.41°	16.52°	19.15°	23.18°	25.94°	27.34°	30.20°	31.66°	36.20°	41.01°	51.94°	66.73°	n/a	n/a	n/a
1	10.01°	12.31°	14.24°	17.17°	19.15°	20.15°	22.17°	23.18°	26.29°	29.48°	36.20°	43.55°	51.94°	79.82°	n/a
1.25 (15")	8.00°	9.82°	11.35°	13.66°	15.22°	16.00°	17.57°	18.36°	20.75°	23.18°	28.19°	33.45°	39.04°	51.94°	n/a
1.5 (18")	6.66°	8.17°	9.44°	11.35°	12.63°	13.28°	14.57°	15.22°	17.17°	19.15°	23.18°	27.34°	31.66°	41.01°	79.82°
2	4.99°	6.12°	7.07°	8.49°	9.44°	9.92°	10.87°	11.35°	12.79°	14.24°	17.17°	20.15°	23.18°	29.48°	47.58°
2.5 (30")	3.99°	4.89°	5.65°	6.78°	7.54°	7.92°	8.68°	9.06°	10.20°	11.35°	13.66°	16.00°	18.36°	23.18°	36.20°
3	3.32°	4.08°	4.70°	5.65°	6.28°	6.59°	7.22°	7.54°	8.49°	9.44°	11.35°	13.28°	15.22°	19.15°	29.48°
4	2.49°	3.06°	3.53°	4.23°	4.70°	4.94°	5.41°	5.65°	6.36°	7.07°	8.49°	9.92°	11.35°	14.24°	21.66°
5	1.99°	2.44°	2.82°	3.39°	3.76°	3.95°	4.33°	4.52°	5.08°	5.65°	6.78°	7.92°	9.06°	11.35°	17.17°
6	1.66°	2.04°	2.35°	2.82°	3.13°	3.29°	3.61°	3.76°	4.23°	4.70°	5.65°	6.59°	7.54°	9.44°	14.24°
7	1.42°	1.75°	2.01°	2.42°	2.69°	2.82°	3.09°	3.22°	3.63°	4.03°	4.84°	5.65°	6.46°	8.08°	12.18°
8	1.25°	1.53°	1.76°	2.12°	2.35°	2.47°	2.70°	2.82°	3.17°	3.53°	4.23°	4.94°	5.65°	7.07°	10.63°
9	1.11°	1.36°	1.57°	1.88°	2.09°	2.19°	2.40°	2.51°	2.82°	3.13°	3.76°	4.39°	5.02°	6.28°	9.44°
10	1.00°	1.22°	1.41°	1.69°	1.88°	1.97°	2.16°	2.26°	2.54°	2.82°	3.39°	3.95°	4.52°	5.65°	8.49°
12	0.83°	1.02°	1.17°	1.41°	1.57°	1.65°	1.80°	1.88°	2.12°	2.35°	2.82°	3.29°	3.76°	4.70°	7.07°
15	0.66°	0.81°	0.94°	1.13°	1.25°	1.32°	1.44°	1.50°	1.69°	1.88°	2.26°	2.63°	3.01°	3.76°	5.65°
20	0.50°	0.61°	0.70°	0.85°	0.94°	0.99°	1.08°	1.13°	1.27°	1.41°	1.69°	1.97°	2.26°	2.82°	4.23°
30	0.33°	0.41°	0.47°	0.56°	0.63°	0.66°	0.72°	0.75°	0.85°	0.94°	1.13°	1.32°	1.50°	1.88°	2.82°
50	0.20°	0.24°	0.28°	0.34°	0.38°	0.39°	0.43°	0.45°	0.51°	0.56°	0.68°	0.79°	0.90°	1.13°	1.69°
75	0.13°	0.16°	0.19°	0.23°	0.25°	0.26°	0.29°	0.30°	0.34°	0.38°	0.45°	0.53°	0.60°	0.75°	1.13°
100	0.10°	0.12°	0.14°	0.17°	0.19°	0.20°	0.22°	0.23°	0.25°	0.28°	0.34°	0.39°	0.45°	0.56°	0.85°
200	0.05°	0.06°	0.07°	0.08°	0.09°	0.10°	0.11°	0.11°	0.13°	0.14°	0.17°	0.20°	0.23°	0.28°	0.42°

meters

LENS TILT REQUIRED FOR DISTANCE J AND FOCAL LENGTH INDICATED

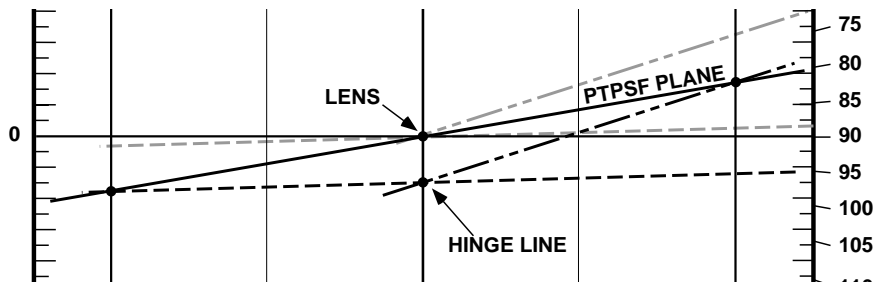
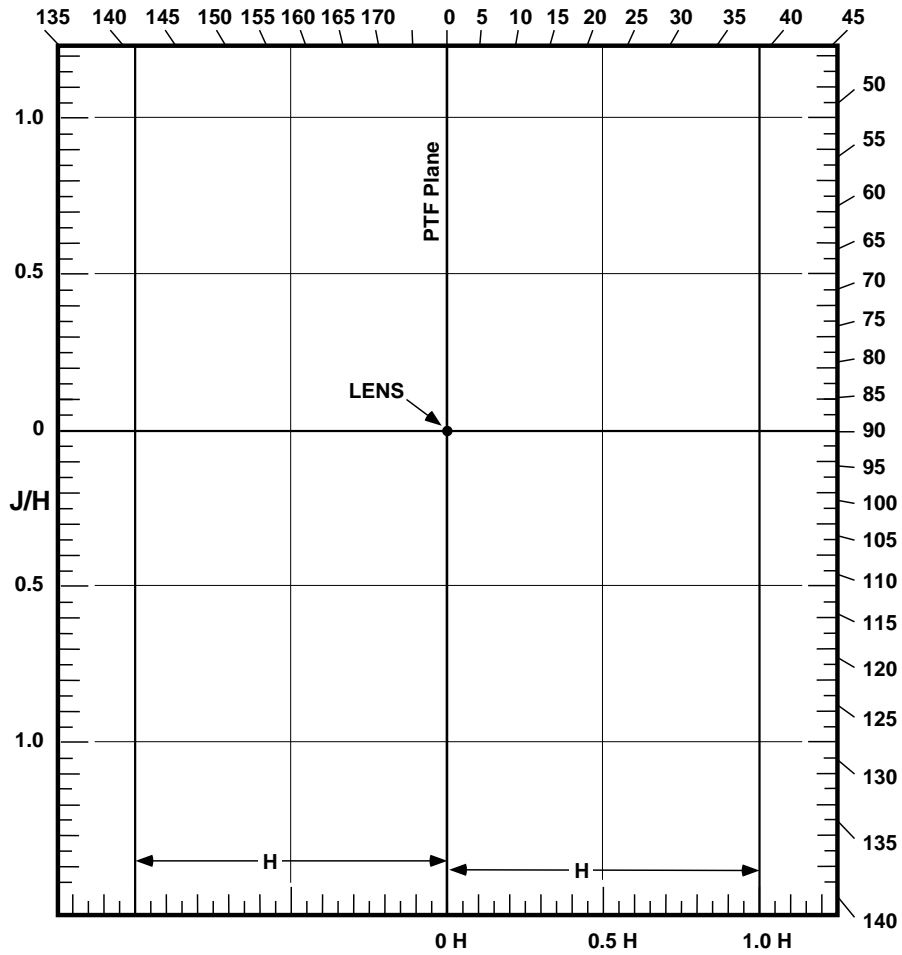
Distance J (in meters)	FOCAL LENGTH (in mm)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
0.1	32.01°	40.54°	48.59°	64.16°	90.00°	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
0.2	15.37°	18.97°	22.02°	26.74°	30.00°	31.67°	35.10°	36.87°	42.45°	48.59°	64.16°	n/a	n/a	n/a	n/a
0.3	10.18°	12.51°	14.48°	17.46°	19.47°	20.49°	22.54°	23.58°	26.74°	30.00°	36.87°	44.43°	53.13°	90.00°	n/a
0.4	7.61°	9.35°	10.81°	13.00°	14.48°	15.22°	16.71°	17.46°	19.72°	22.02°	26.74°	31.67°	36.87°	48.59°	n/a
0.5	6.08°	7.47°	8.63°	10.37°	11.54°	12.12°	13.30°	13.89°	15.66°	17.46°	21.10°	24.83°	28.69°	36.87°	64.16°
0.75	4.05°	4.97°	5.74°	6.89°	7.66°	8.05°	8.82°	9.21°	10.37°	11.54°	13.89°	16.26°	18.66°	23.58°	36.87°
1	3.04°	3.73°	4.30°	5.16°	5.74°	6.03°	6.60°	6.89°	7.76°	8.63°	10.37°	12.12°	13.89°	17.46°	26.74°
1.5	2.02°	2.48°	2.87°	3.44°	3.82°	4.01°	4.40°	4.59°	5.16°	5.74°	6.89°	8.05°	9.21°	11.54°	17.46°
2	1.52°	1.86°	2.15°	2.58°	2.87°	3.01°	3.30°	3.44°	3.87°	4.30°	5.16°	6.03°	6.89°	8.63°	13.00°
2.5	1.21°	1.49°	1.72°	2.06°	2.29°	2.41°	2.64°	2.75°	3.10°	3.44°	4.13°	4.82°	5.51°	6.89°	10.37°
3	1.01°	1.24°	1.43°	1.72°	1.91°	2.01°	2.20°	2.29°	2.58°	2.87°	3.44°	4.01°	4.59°	5.74°	8.63°
4	0.76°	0.93°	1.07°	1.29°	1.43°	1.50°	1.65°	1.72°	1.93°	2.15°	2.58°	3.01°	3.44°	4.30°	6.46°
5	0.61°	0.74°	0.86°	1.03°	1.15°	1.20°	1.32°	1.38°	1.55°	1.72°	2.06°	2.41°	2.75°	3.44°	5.16°
6	0.51°	0.62°	0.72°	0.86°	0.95°	1.00°	1.10°	1.15°	1.29°	1.43°	1.72°	2.01°	2.29°	2.87°	4.30°
7	0.43°	0.53°	0.61°	0.74°	0.82°	0.86°	0.94°	0.98°	1.11°	1.23°	1.47°	1.72°	1.96°	2.46°	3.69°
8	0.38°	0.47°	0.54°	0.64°	0.72°	0.75°	0.82°	0.86°	0.97°	1.07°	1.29°	1.50°	1.72°	2.15°	3.22°
9	0.34°	0.41°	0.48°	0.57°	0.64°	0.67°	0.73°	0.76°	0.86°	0.95°	1.15°	1.34°	1.53°	1.91°	2.87°
10	0.30°	0.37°	0.43°	0.52°	0.57°	0.60°	0.66°	0.69°	0.77°	0.86°	1.03°	1.20°	1.38°	1.72°	2.58°
12	0.25°	0.31°	0.36°	0.43°	0.48°	0.50°	0.55°	0.57°	0.64°	0.72°	0.86°	1.00°	1.15°	1.43°	2.15°
15	0.20°	0.25°	0.29°	0.34°	0.38°	0.40°	0.44°	0.46°	0.52°	0.57°	0.69°	0.80°	0.92°	1.15°	1.72°
20	0.15°	0.19°	0.21°	0.26°	0.29°	0.30°	0.33°	0.34°	0.39°	0.43°	0.52°	0.60°	0.69°	0.86°	1.29°
25	0.12°	0.15°	0.17°	0.21°	0.23°	0.24°	0.26°	0.28°	0.31°	0.34°	0.41°	0.48°	0.55°	0.69°	1.03°
30	0.10°	0.12°	0.14°	0.17°	0.19°	0.20°	0.22°	0.23°	0.26°	0.29°	0.34°	0.40°	0.46°	0.57°	0.86°
50	0.06°	0.07°	0.09°	0.10°	0.11°	0.12°	0.13°	0.14°	0.15°	0.17°	0.21°	0.24°	0.28°	0.34°	0.52°

**HYPERFOCAL DISTANCES (H)
FOR DIAMETER OF CIRCLE OF CONFUSION EQUAL TO f/1500**

f-number, N	FOCAL LENGTH (in millimeters)														
	53	65	75	90	100	105	115	120	135	150	180	210	240	300	450
	Hyperfocal distances in meters														
2.8	28.4	34.9	40.3	48.3	53.7	56.4	61.7	64.4	72.5	80.5	96.6	112.7	128.8	161.0	241.5
4	19.9	24.4	28.2	33.8	37.6	39.5	43.2	45.1	50.8	56.4	67.7	79.0	90.2	112.8	169.2
5.6	14.2	17.5	20.2	24.2	26.9	28.2	30.9	32.3	36.3	40.3	48.4	56.5	64.5	80.7	121.0
8	10.0	12.3	14.1	17.0	18.9	19.8	21.7	22.6	25.4	28.3	33.9	39.6	45.2	56.6	84.8
11	7.3	8.9	10.3	12.4	13.7	14.4	15.8	16.5	18.5	20.6	24.7	28.8	33.0	41.2	61.8
16	5.0	6.2	7.1	8.5	9.5	9.9	10.9	11.4	12.8	14.2	17.1	19.9	22.7	28.4	42.6
22	3.7	4.5	5.2	6.2	6.9	7.3	8.0	8.3	9.3	10.4	12.5	14.5	16.6	20.8	31.1
32	2.5	3.1	3.6	4.3	4.8	5.0	5.5	5.7	6.5	7.2	8.6	10.1	11.5	14.4	21.5
45	1.8	2.2	2.6	3.1	3.4	3.6	3.9	4.1	4.6	5.2	6.2	7.2	8.2	10.3	15.5
64	1.3	1.6	1.8	2.2	2.4	2.6	2.8	2.9	3.3	3.7	4.4	5.1	5.9	7.3	11.0
90	0.9	1.1	1.3	1.6	1.8	1.9	2.0	2.1	2.4	2.7	3.2	3.7	4.2	5.3	8.0
	Hyperfocal distances in feet														
2.8	93.3	114.5	132.1	158.5	176.1	184.9	202.5	211.3	237.7	264.1	317.0	369.8	422.6	528.3	792.4
4	65.4	80.2	92.5	111.0	123.4	129.5	141.9	148.0	166.5	185.0	222.0	259.1	296.1	370.1	555.1
5.6	46.7	57.3	66.2	79.4	88.2	92.6	101.4	105.8	119.1	132.3	158.8	185.2	211.7	264.6	396.9
8	32.8	40.2	46.4	55.7	61.8	64.9	71.1	74.2	83.5	92.8	111.3	129.9	148.4	185.5	278.3
11	23.9	29.3	33.8	40.6	45.1	47.3	51.8	54.1	60.8	67.6	81.1	94.6	108.2	135.2	202.8
16	16.5	20.2	23.3	28.0	31.1	32.6	35.7	37.3	42.0	46.6	56.0	65.3	74.6	93.3	139.9
22	12.0	14.8	17.0	20.4	22.7	23.8	26.1	27.2	30.6	34.0	40.9	47.7	54.5	68.1	102.1
32	8.3	10.2	11.8	14.1	15.7	16.5	18.1	18.8	21.2	23.6	28.3	33.0	37.7	47.1	70.7
45	6.0	7.3	8.4	10.1	11.3	11.8	13.0	13.5	15.2	16.9	20.3	23.7	27.0	33.8	50.7
64	4.2	5.2	6.0	7.2	8.0	8.4	9.2	9.6	10.8	12.0	14.4	16.8	19.2	24.1	36.1
90	3.1	3.8	4.3	5.2	5.8	6.1	6.7	7.0	7.8	8.7	10.4	12.2	13.9	17.4	26.1

$H = f + f^2/g$; $g = Na$ (f = focal length, N = f-number, a = dia. of circle of confusion, g = depth of focus, either side of film plane.) If **$a = f/Q$** , **$H \approx Q \times$** diameter of lens aperture.

Focusing the View Camera — © Harold M. Merklinger, January 1993



Depth of Field measured Parallel to Film: $L_{pf} = ZJ/H$

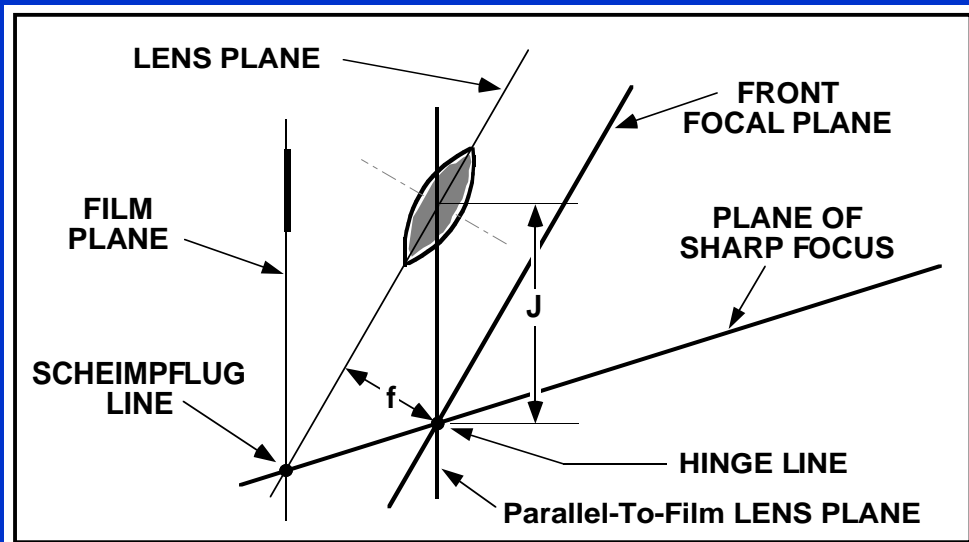
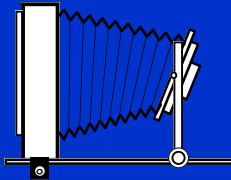
Focusing the View Camera — © Harold M. Merklinger, January 1993

FOCUSING the VIEW CAMERA is intended for all users of the view camera, whether they be veteran professionals or new apprentices. The book will help all such photographers to understand the optical principles behind the camera's remarkable flexibility, and to manipulate lens tilt and swing with confidence.

The well-known Scheimpflug Principle is one of two such rules that determine camera focus. The second rule, called the "Hinge Rule" in this book, is almost unknown. The Hinge Rule will allow the photographer to set the required lens tilt and swing perhaps even before the camera is mounted on the tripod! The Hinge Rule also helps us determine the depth of field boundaries for view cameras.

This book contains many tables that enable the photographer use the Hinge Rule easily, and to delineate depth of field for tilted lenses. But an approximate method is also described for estimating depth of field. And the approximate method is simple enough to be carried around in one's head!

If you use a view camera, this book is a "must-have".



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