A large format Photographer's *vade mecum**

HP48GX and HP49 program documentation

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1 Introduction

When a university education was mostly a study of Greek and Latin, schoolboys carried about small books containing crib notes, grammatical memoranda, and other helpful bits of information. It is not surprising that they referred to them by a Latin tag, *vade mecum*, which translates as "go with me." I, and I think most large format photographers, do something similar. In my bag is a notebook filled with various things, such as filter factors, reciprocity times, shift limits for various lenses, etc.

In addition, I carry one other thing, which I consider my real *vade mecum*. It is an HP48GX pocket calculator, and in it I have programmed those calculations that are useful for my sort of photography. Yesterday, for example, I took two pictures while on a walk. One required a tilted lens, and the other involved a nice calculation of DOF to include an object in the foreground. Neither took more than five minutes, and a third photograph was abandoned before the camera was unpacked, because preliminary calculations indicated that it could not be taken in the way I envisioned — I'll probably go back and rethink the composition sometime.

When I started in large format photography, I was unable to find adequate instructions for many fiddling problems in the books I consulted. I found exhaustive discussion of light and photographic materials, but little help on the practical problems. Lens tilt, for example, seemed as much a mystery to many authors of photography books as it did to me — at least if they knew its incantation, they chose not to reveal it.

As near as I could make out, tilting the lens was something to be done by cut-and-try — focus on something, tilt the lens a bit, focus on something, adjust the tilt, etc. until all parts of the subject are in focus[1]. I tried this a few times with middling success, but found it hardly a satisfactory procedure: if for no other reason, than that it takes a long time. I am sure the information exists in the technical literature somewhere, but in exasperation I sat down and derived the equations from first principles. By that I mean I went back to a theorem of projective geometry due to Desargues which underlies the rules artists use to produce perspective drawings, and derived the lens equation relating the focus distance, the lens-film distance, and the lens focal length. From this everything else follows.

The programs described here, calculate the lens tilt angle in several ways. The easiest is by focusing on two points in the subject plane, which is the idea that underlies the Sinar, and Linhoff built-in calculations. Almost as easy, is to use the distance and angle of a pair of points in the subject plane. There are two additional methods which may appeal to some who fancy that they can judge angles by eye.

Of course, a photographer has other problems: depth of field, DOF, for one. The standard formulas that appear in books work well enough for intermediate and distant objects, but are considerably in error for macro photography. This

[1] A discussion of this procedure in exquisite detail may be found in Bond (1998).

is strange, since the correct formulas are not difficult. Perhaps the authors have stuck to formulas that they thought would be easy to calculate. In any case, if one is going to use a calculator, which I hope you will, then there is no need to use the wrong formula. In addition, the practicing photographer needs to make judgments about DOF for tilted lenses, and assess the degree of blur for a background or foreground object. Six programs are provided for these problems, differing in the type of input required.

Various questions arise in practice about focal length: (1) given near and far objects, which focal length will cause these to be the near and far DOF limits? (2) Given the magnification and the distance to the subject, what is the proper focal length to choose. Similar questions occur in relation to the proper F-number. And what about the bellows factor? There are other questions still – what shutter speed will stop motion, or what is the angle of view? Programs are provided for all.

Perhaps the most important thing, is the viewframe: a simple frame made from what you will with a measuring cord attached. I am not aware of any serious discussion of this most useful device. It not only concentrates the photographers attention by framing the view, but enables the appropriate lens to be chosen, and with the two programs included, allows the photographer to find the DOF – all without unpacking the camera.

The programs may be entered into a calculator by hand, or they may be downloaded from a PC via a serial cable. Instructions for downloading are given in an associated document. The mathematical details of many of these calculations do not seem to be available in the literature, and so a collection of notes may also be downloaded.

I assume that the reader is a large format photographer, and that the problems discussed will be those that have been thought about. I wouldn't discourage someone who is new to this format from reading this material and using the programs, but I think it unlikely that they will fully appreciate the programs until they have experienced some of them firsthand. There are a number of good[2] books on large format photography, and I would hope that the neophyte would consult them first. Two that I can recommend are: Stroebel et.al. (1986), Stroebel (1993) For the more technically inclined, Ray (1994) and Jacobson et.al. (1988) are also good.

1.1 Notation

I have chosen to use a few standard symbols both in the programs and in this text, rather than repeat descriptive phrases at every point. They are illustrated in Figure 1, and listed in Table 1. The figure shows three planes: the subject plane, the lens plane, and the focal plane. In addition, the Near and Far DOF planes are shown about the subject plane, as are their cognates about the focal plane. Note that the Near and Far planes are measured from the lens plane.

[2] Although on topic, I cannot recommend Merklinger (1992) or (1993) because simple ideas are made overly complicated.

The distances of these planes from the subject plane are denoted FrontDOF and BackDOF. The Near and Far planes are not symmetrical about the subject plane, but their cognates about the focal plane are symmetrical, for all practical purposes. Thus one may use $\delta/2$ to represent the distance from either to the focal plane. The lens tilt angle, θ, will be discussed later.

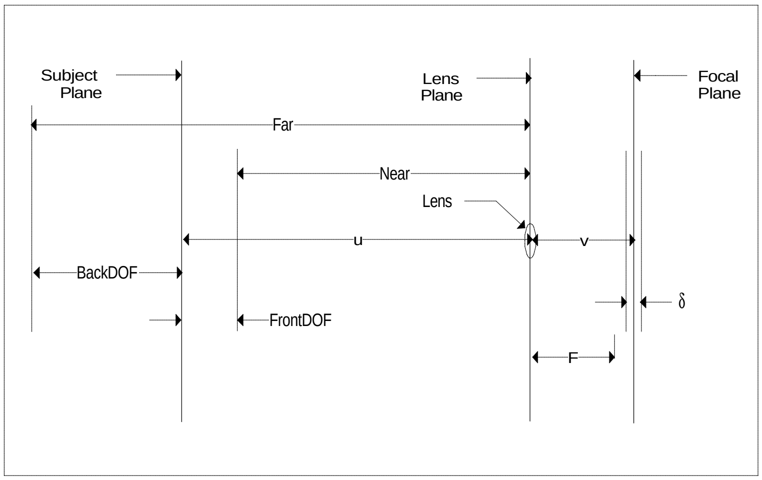


Figure 1: Parallel planes

u	Distance from subject focus point to lens
v	Distance from lens to film
F	Focal length
N	The F-number
δ	Defocus $\equiv$ Depth of focus
θ	Lens tilt angle
Near	Near DOF limit
Far	Far DOF limit
FrontDOF	$= (u - Near)$: i.e. DOF in front of focus
BackDOF	$= (Far - u)$: i.e. DOF in back of focus

Table 1: Frequently used symbols

In addition, units of measurement are indicated by appending a unit designator starting with an underline "_" to values. Thus 5_m means 5 meters, 3_mm means 3 millimeters, 10_° means 10 degrees, etc.

1.2 Fractional stops

The N values are spaced uniformly on the shutter, and one can set intermediate values, such as a value half way between 16 and 22. The corresponding N is

19.6, which requires some calculation to discover, and would be a nuisance were the programs to demand its input. Therefore, the programs allow the input of intermediate values using the form "16_5", where both the quotes and the "_" are required. "16_5" may be read as the shutter setting half way between 16 and 22. In actuality, the program translates the quoted string into a number (19.6) which it stores in the variable N; and when it displays N, it displays a quoted string if needed. Full F-numbers may be input either as numbers[3], like 16, or as strings with quotes like "16."

1.3 Numerical accuracy

The amount of light admitted through the aperture (illuminance) is of great importance, as early photographers quickly learned. It may be controlled by the duration of the exposure and by the lens aperture. About 1880 (Kingslake 1989) it became customary to designate a lens by its F-number. Iris shutters were also introduced about 1880 (*ibid*), and markings on the lenses were likely to have been in terms of F-numbers. Sequences of stops and F-numbers were proposed at the turn of the century, but the present standard sequence of F-numbers (1, 1.4, 2, 2.8, 4, ...) is fairly recent.

There is not a lot that can be said in justification of this standard sequence for a practical photographer. It requires an act of memory to use, and it increases as the illumination decreases, which is contrary to what one wants. One way to think of it is as a measure of the luminance of the object, in which case a small opening and large F-number represents a bright object, but the odd sequence is still something to remember.

Twice the base 2 logarithm of the F-number sequence is (0, 1, 2, 3, ...), which would make things easier if only cameras were marked this way[4]. In this sequence, the steps represent a halving of the light intensity, so that 3 represents half the light intensity of 2. For intermediate values, light meters report the decimal fraction from this scale: thus one may read 1.4$_5$ on a light meter, representing a tic half way between the f/1.4 and f/2 tics on a camera[5]. Shutters on automatic cameras can be capable of controlling aperture to a tenth of a step, but others may not be so accurate. A likely practical limit is a setting to the nearest 1/3 stop.

The notation adopted herein is 1.4_5. The "_" is required. The programs read and write numbers in this form, but internally they are translated into F-numbers, so that 1.4_5 is translated into $N = 1.68$.

2 Setting parameters

Program Name: P

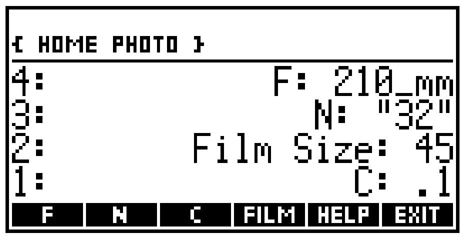
[3] Actually input numbers are rounded to the nearest F-number before assignment to the variable N, so inputting 20 results in N being set to 16.

[4] The EV system was originally developed for this purpose, but never became popular.

[5] Such an intermediate tic does not represent the halfway intensity of 75%, but rather about 71%.

Four parameters are needed for most calculations. They are focal length, F, the F-number, N, the format and optionally C, the diameter of the circle of confusion. It is incumbent on the user to make sure that they are always current. Some programs use them, others do not, but it is a waste of time to try to remember which is which, so always make sure they are current.

They may be set by running the P program. This can always be done by entering [6] *P* or pressing the corresponding menu key if it is visible. This function throws up a display showing the current values, and then shows a menu along the bottom, as in the following screen capture:



To change the F or N values, enter a new value in the calculator and press **F** or **N**. To change the film size, press **FILM** and choose one of the options: they are 35mm, 645, 6x7, 6x9, 4x5, and 8x10. In general C should not be changed. A film size change will set C to a standard value, which may then be changed if desired. When the parameters are correct, press the **EXIT** key. The need for pressing **EXIT** can be confusing since this is the only program requiring it. All other programs perform their calculations, display them, and exit automatically.

Illustrations in the rest of this document assume the parameters are set as in the above screen capture – F at 210 mm, N at 32, and FILM at 45.

3 The viewframe

Even before the camera is set up, a decision about the view to be captured should be made. This is aided considerably by the use of a simple viewframe held so as to frame the scene. Almost anything with the right sized hole will do — I use a bent coat hanger. The inside dimensions should be the same as the size of the image on the film. In addition some means should be provided for measuring the distance from the viewframe to the eye. I attach a flexible tape marked in millimeters to my viewframe. Figure (2) shows some items from my gadget bag, among them may be seen my bent coat hanger viewframe.

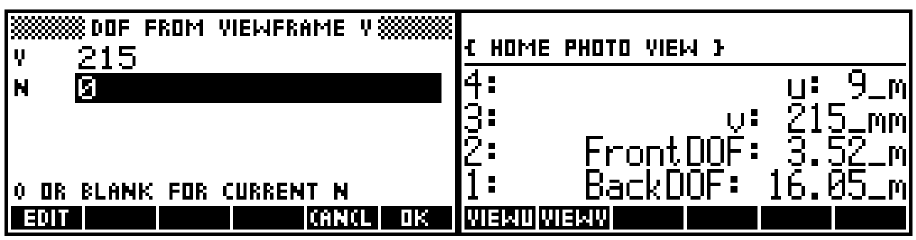
Use the viewframe to frame the view, and note either of two distances: (1) the distance, v, from the viewframe to one eye — the other should be closed, since a camera has only one eye; or (2) the distance, u, to the point of focus. The following two programs will provide depth of field and other information.

[6] Press α, then **P**, then **ENTER**

Figure 2: Gadgets

3.1 Program Name: VIEWV, From v

The program asks for two parameters. The input is on the left, the output on the right.

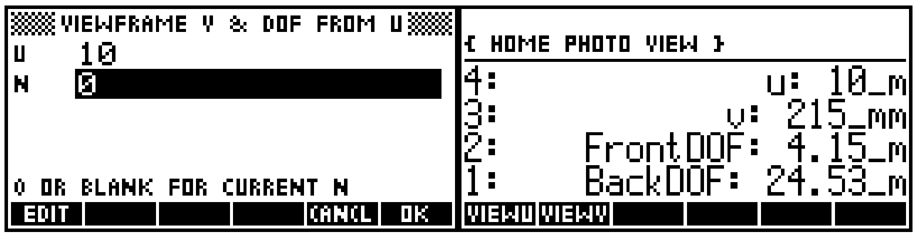


Here v is the distance in millimeters from the lens to the film plane. The F-number, N, may be input since one sometimes needs to compare the effects of different N. If N is input as 0 or blank (i.e. as "") the current value of N, set by the P program, will be used. This current value is unchanged by VIEWV.

On the output, the u value is the distance from the lens to the in-focus subject. The FrontDOF and BackDOF values are the distances from u to the near and far DOF limits. In this illustration, the DOF is 19.57 m (3.52 + 16.05).

3.2 Program Name: VIEWU, From u

The program asks for two parameters. The input is on the left, the output on the right.



The only difference from the previous program, is that u, the focus distance, is input. The F-number, N, may be input since one sometimes needs to compare the effects of different N. If N is input as 0 or blank (i.e. as "") the current value of N, set by the P program, will be used. This current value is unchanged by VIEWU.

The u value is repeated from the input, and the v value calculated. The FrontDOF and BackDOF values are the distances from u of the near and far DOF limits.

3.3 Discussion

A viewframe improves the visualization of a composition. It aids in deciding the composition's orientation (landscape or portrait), and aids in the elimination of extraneous detail which the eye might otherwise not notice. There are other uses.

It may be used to find the appropriate focal length. Suppose a composition frames nicely in the viewframe when the subject is about 4 m away, and that the viewframe to eye distance, v, is about 220 mm. Any lens with less than 220 mm focal length may be chosen and then extended to 220 mm for focusing. A 210 mm might be appropriate. Of course one could also choose a 150 mm, but the extension to 220 m (150 mm + 70 mm) would result in a bellows factor of about 2. In this case, VIEWV using $v = 220$ m indicates the FrontDOF and BackDOF values are 1.12 m and 2.17 m, assuming $F = 210$ and $N = 32$.

In making a decision about focal length, there is no need to be overly precise about v. A few millimeters either way will not change the composition much. The important thing is to decide on a focal length with approximately the coverage desired and leave the fine details to that time when the camera is focused.

Using a viewframe in this way is quite easy. What happens if one needs more depth of field, such as a foreground object? I raise the point, because some will attempt to adjust the DOF by changing their lens. There is nothing wrong with this if it meets the artistic needs, but often the resulting change distorts the composition. Extraneous detail which was outside the frame is now included, or the composition loosens up and becomes uninteresting. To keep the same composition when changing the lens, the camera must be moved. This will keep the magnification constant. Unfortunately, the DOF does not change very much when magnification is fixed. You might like to use the DOFM program which gives DOF as a function of magnification to establish the truth of this statement[7].

To increase DOF in a substantial way, the F-number, N, must be changed. In this case doubling N from 32 to 64, produces $FrontDOF = 1.8$ m and $BackDOF = 8.21$ m. The composition remains unchanged.

4 Determining lens tilt

When the subject, lens, and film planes are parallel, focusing on any one part of the subject focuses on all parts. This is illustrated in Figure (1).

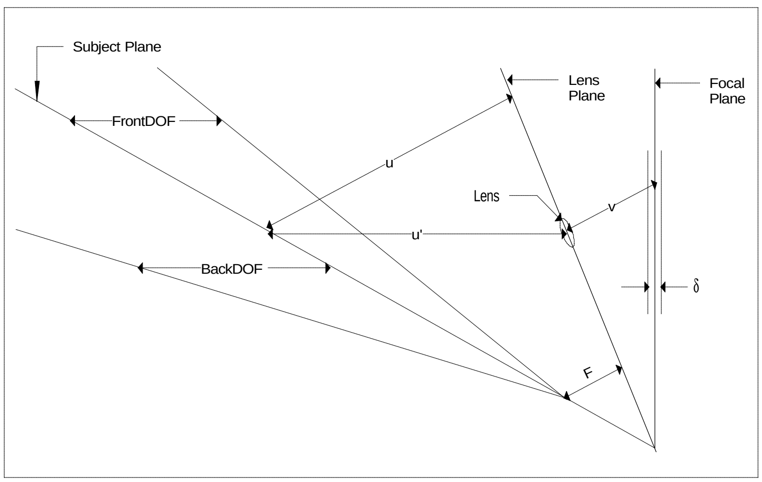


Figure 3: Tilted planes

This is not true when the subject plane lies at an angle to the other planes. Focusing on one part of the tilted subject plane may cause other parts to be out of focus. To bring all parts of the subject into focus, the lens must be tilted so that all three planes meet at a line. This is Scheimpflug's rule. Figure (3) illustrates this rule. The parallel planes in Figure(1) also obey Scheimpflug's rule if one agrees, as is usual, that parallel planes meet at infinity.

If the subject plane is tilted, then it will meet the focal plane somewhere. The problem is to find the tilt angle of the lens such that a plane through it will also meet where the other two planes meet. Many experienced photographers decide on the tilt angle by cut-and-try mixed with considerable experience. If the ground glass were brightly illuminated, I would not find much fault with

[7]The magnification for the above illustration is about 0.021, which can be found from the MAGV program.

such a procedure: but it is not, it is almost always dim requiring a dark cloth to block light, and for some lens's with small maximum apertures, the ground glass can be grainy making nice judgments difficult. I prefer to calculate the angle from observations, and the following programs do this. The *BACK TILT* parameter which appears in the input menus of the following programs will be discussed in Section (4.4).

It is important to note, that although "tilt" is used in this section, the information applies equally to "swing."

4.1 TILTB, By back focusing

The easiest way to determine lens tilt is by focusing on two subjects which image near the top and bottom of the ground glass. Figure (4) shows this for two back positions, one when point A is in focus, and one when point C is in focus. The distance along the rail (in millimeters) between the focus points, together with the distance between the images (in millimeters) on the ground glass can be used to determine lens tilt. In figure (4) the Rail Δ is the distance from a to b, and the Glass Δ is the distance from b to c. The calculation of the lens tilt angle in degrees is given approximately by Wheeler's rule of 60. To wit $\phi \approx 60(b-a)/(c-b)$. The rule is not appropriate for close up work, but the TILTB program always gives the correct value.

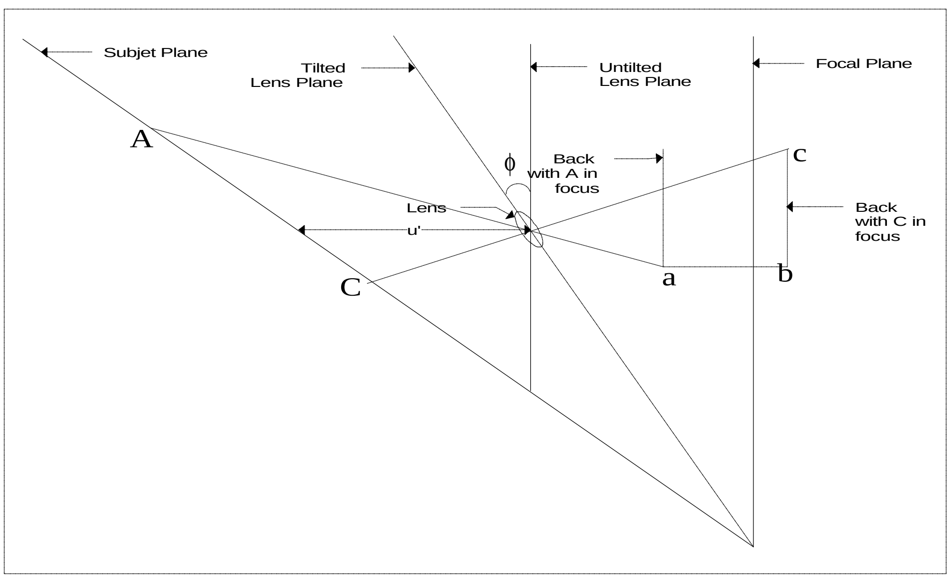
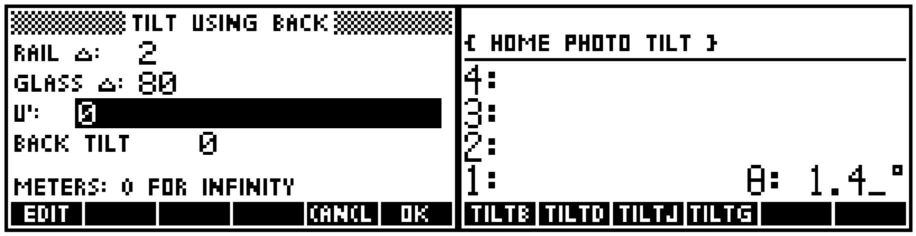


Figure 4: Tilt Diagram

The program input is on the left and the program output on the right. The input uses the distance u' shown in Figure(4) which is the horizontal distance to the subject plane. The tilt calculation does not make use of u', but it is used in calculating the slope γ of the subject plane, which parameter is saved for later use by *DOF*\$.



The program outputs the lens tilt angle in degrees. The angle is positive for forward tilts, and negative for backward. Once the lens is tilted, and refocused, all points in the lens plane will be in focus.

In refocusing after the lens tilt, those with center tilt cameras will find the focus point somewhere between the two previous points, while those with base tilt cameras will find it necessary to move the rear standard a considerable distance forward. Base tilt cameras move the lens in addition to rotating it, and the rear standard must be brought forward to adjust for this movement.

4.2 TILTD, Tilt from distance and angle

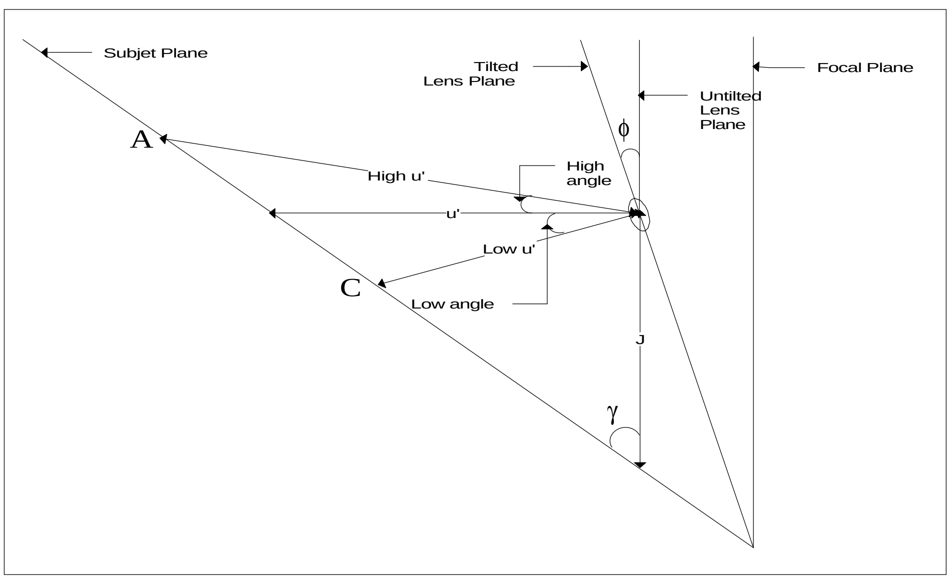
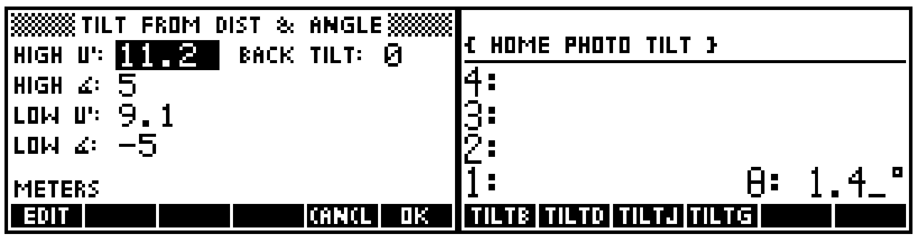


Figure 5: Distance and angle

Another way to determine lens tilt is by specifying the angles and distances to two objects in the desired subject plane. Figure (5) shows two points A and C on the subject plane. The distances and angles of these points are input to TILTD. The program assumes that angles above the horizon are positive, and negative below the horizon. One can buy palm size devices to measure angles above and below the horizon from shops that sell surveyors's equipment. Distance can be guessed. The calculations are not very sensitive to the far distance, but the near distance should be as accurate as possible. If a compass is available, then the program TRIAN may be used to triangulate from two bearings — the compass must read in degrees or finer. The program input is on the left, the output on the right.

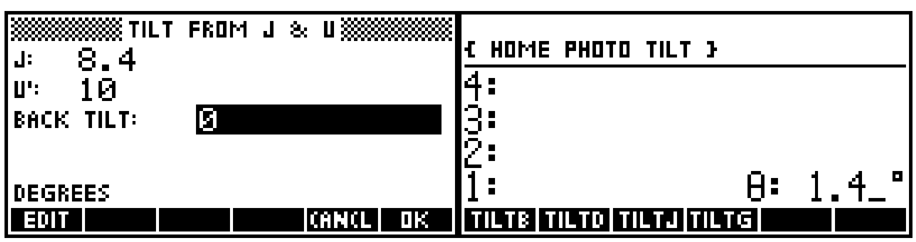


4.3 Tilt from geometric parameters

The next two programs ask for inputs derived from the geometry of the problem. These inputs can often be guessed with reasonable accuracy, and may prove easier to use in certain circumstances. Figure (5) shows the planes and rays involved for lens tilt calculations. The distance J is the vertical distance from the lens center to the subject plane, and γ is the angle that the subject plane makes with the lens plane.

4.3.1 TILTJ, Tilt from J

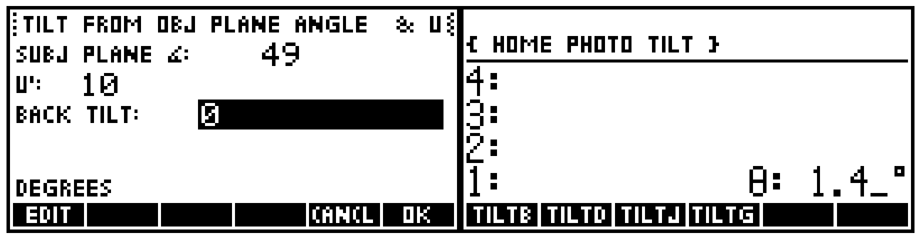
The values of J and u' are guessed. The output is shown at the right.



Merklinger (1992) and (1993) recommends this method using J alone, which is all that is required to calculate the tilt angle θ. TiLTJ asks for u' in order to calculate γ which is needed for DOF$.

4.3.2 TILTG, Tilt from γ

Guessing the subject plane angle γ and u'. The output is shown at the right.



4.4 Tilting the back

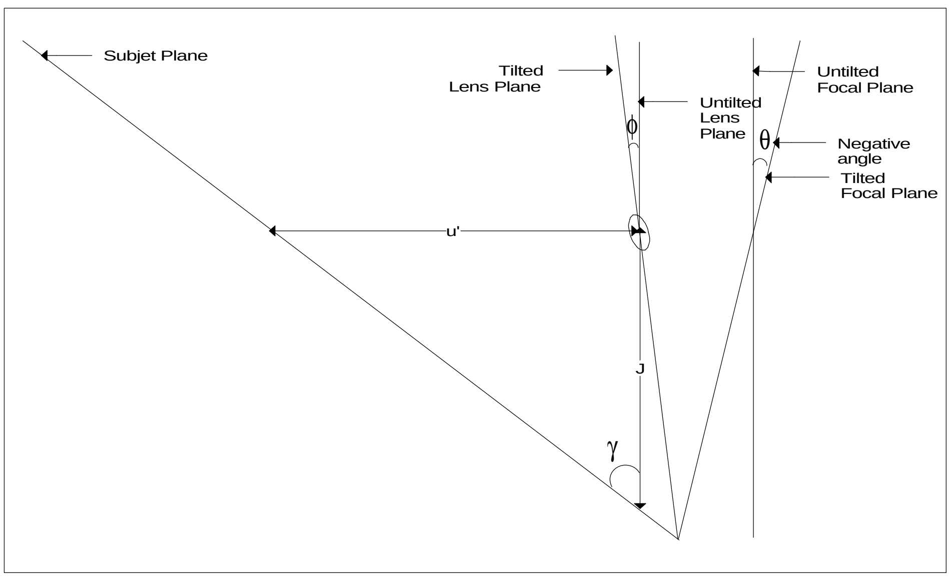
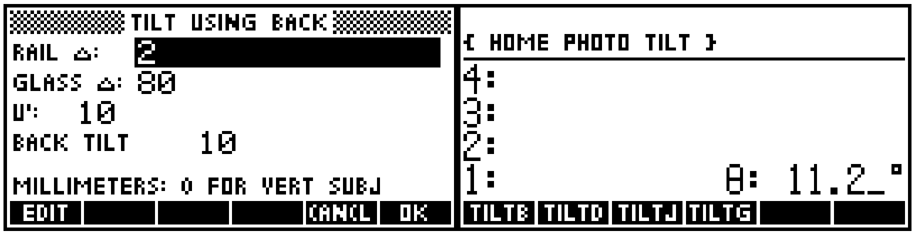


Figure 6: Tilted back

Tilting the back changes perspective by altering the way lines converge to vanishing points. Sometimes this change is desired. Scheimpflug's rule still applies when the back is tilted, as Figure (6) shows. The appropriate lens tilt angle will be calculated by each of the above programs when the *Back Tilt* parameter is input. The input parameters should be obtained with an untilted back precisely as has been done above. The only change in the program input, is the setting of *Back Tilt* to a non-zero value. Consider the TILTB example above:



With the back tilted forward 10°, and the lens tilted 11.2° the subject plane will be in focus, although previously parallel vertical lines will diverge. It is assumed that positive back tilt angles imply a forward back tilt, and negative angles a backward tilt, just as they do for the lens tilt.

Back tilts can be used even when the subject plane is vertical. The programs will output the necessary lens tilt degrees. For TILTB, a vertical subject plane is indicated by setting the Rail Δ to 0. The Glass Δ must have a non-negative value. For TILTD, the distances and angles must specify a vertical plane. For TILTJ and TILTG inputting 0 for J and 0 for γ, the subject plane angle, indicates a vertical subject plane.

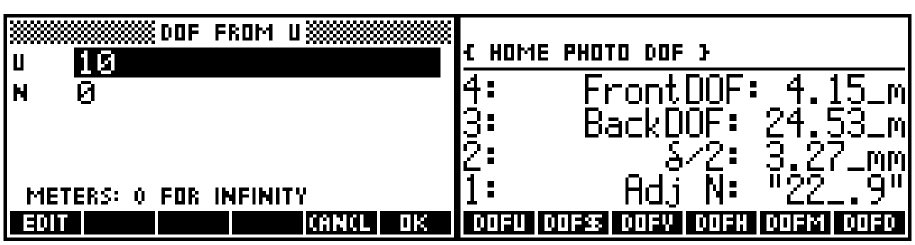
5 Determining DOF

DOF is an important topic, and the photographer needs to assess it in several ways. The usual way is to calculate DOF as a function of u. But one can also use v, subject height, magnification, or the defocus δ. Programs are provided for each of these input values, as well as one that calculates the DOF along an arbitrary ray when the lens is tilted. Please refer to Figures (1) and (3). In addition, there is a program to calculate the hyperfocal distance, one that assesses the *blur* of objects at various distances, and two that translate DOF to and from δ.

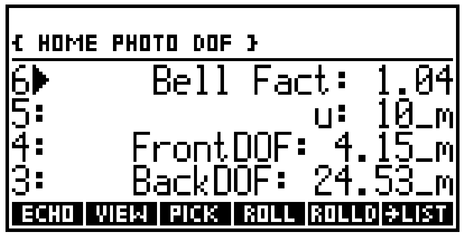
All DOF programs report the same information, so this output will be described more fulsomely in the next subsection, (5.1) than in the other subsections.

5.1 DOFU, As a function of u

The input is u, and the initial output is shown on the right.



The Bellows factor and the parameter u appear above the top of the output list, and are not initially visible. To see them one must scroll the display, as is done here:



All DOF programs output u. For DOFU, it is input. For other DOF programs it is calculated. The FrontDOF and BackDOF are distances about u. Thus the near point of the depth of field is $u - FrontDOF$, and the far point is $u + BackDOF$.

The defocus distance δ is the distance on the rail corresponding to DOF, see Figure(1). For practical purposes, this distance is symmetrical about v, the distance on the rail corresponding to the subject distance u. Thus, the points $v - \delta/2$ and $v + \delta/2$ are defocus limits, corresponding to near and far DOF limits. One can use the defocus limits to locate the near and far DOF planes. Simply move the standard back or forward by $\delta/2$ and observe those objects in sharpest focus — these correspond to objects on one of the DOF planes.

The adjusted F-number, Adj N, shown is the bellows corrected F-number. In this case, the original F-number, N, was 32. Allowing for the bellows extension produces a value of 22.9, which is not practically different from 32.

> *Before releasing the shutter, it is always a good idea to perform a DOF calculation in order to check the bellows effect on the F-number – surprises do occur.*

The DOF limits shown by the DOF programs are calculated assuming the input N. If the adjusted N differs practically from this N, and if the adjusted N is actually used to set the shutter, it will be necessary to recalculate the DOF limits by inputting the adjusted N to DOFU. Of course a doubly adjusted N will be output, but this should be ignored.

5.2 DOF$, From ray angle, for tilted lenses

In order to set parameters that will be used by DOF$, it is necessary to run one of the tilt programs. Other programs may intervene. DOF$ uses the parameters from the last run TILT program, and no other programs tinker with the saved TILT parameters.

The DOF$ program accepts a single input, an angle, and outputs the FrontDOF and BackDOF values along a ray at this angle to the horizontal. Figure (7) illustrates the situation. Assuming that TILTB has been run with the following

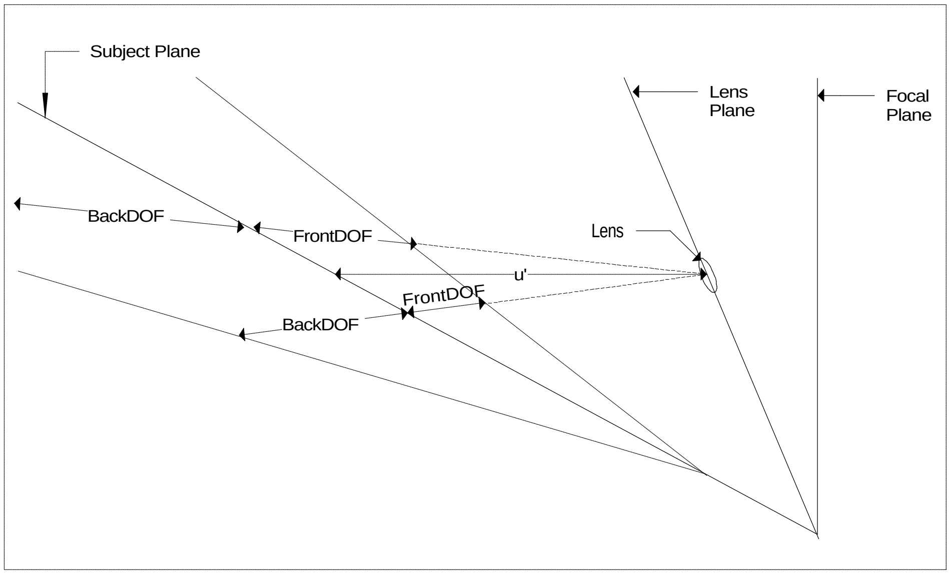
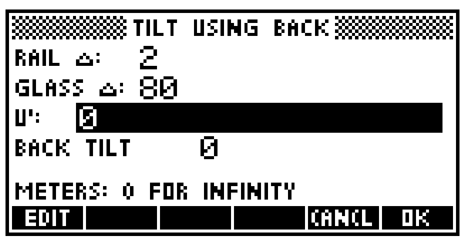
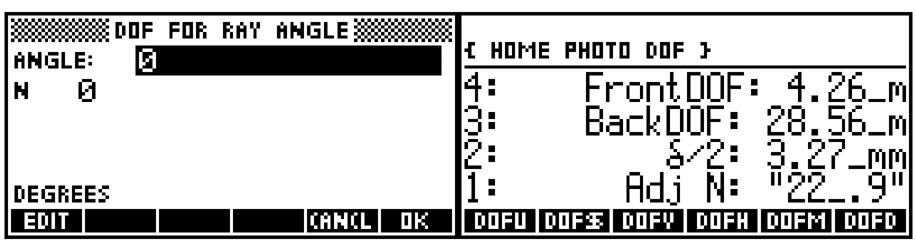


Figure 7: DOF for tilted lens

parameters

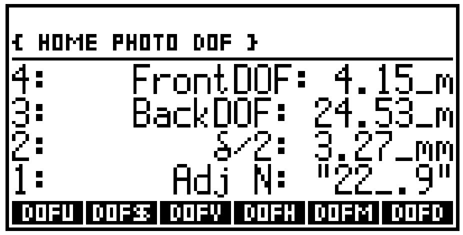


then inputting the angle zero into DOF$, as on the left, produces the output on the right.



Scrolling up would show that $u = 10$, which was the value input in TILTB.

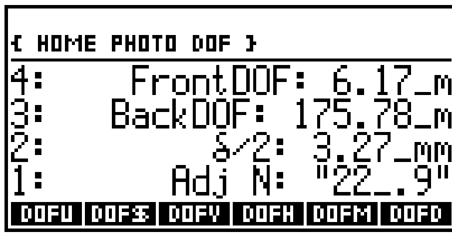
This calculation represents DOF for horizontal distances through a tilted lens. It can be compared with the output of DOFU for an untilted lens:

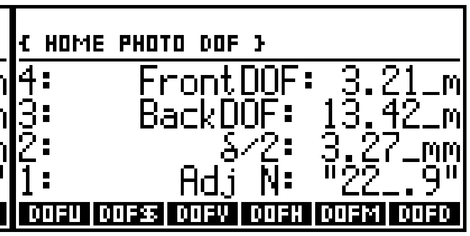


.

There seems to be little difference, but this is not the case when one looks along rays at an angle.

The output resulting from an angle of 10° is shown below on the left, and −10° on the right. The corresponding u's are 12.78 m and 8.42 m.



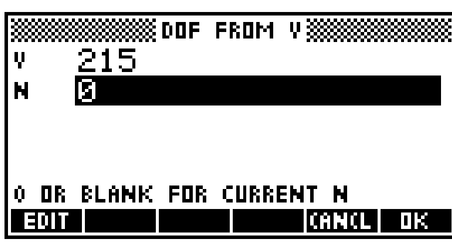


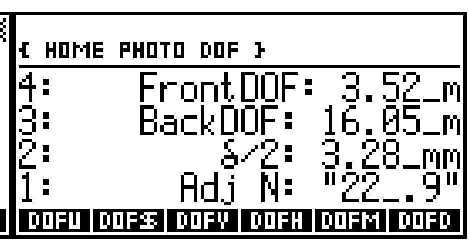
The effect of lens tilt on DOF is substantial.

It is important to note that the defocus, δ may be used to find the near and far DOF planes for tilted lenses, just as it can be for untilted lenses. The defocus limits are $v - \delta/2$ and $v + \delta/2$, and the distance v is the position of the rear standard when the subject plane is in focus. By moving the rear standard forward or back $\delta/2$ millimeters the DOF planes are those which are in sharpest focus.

5.3 DOFV, From v

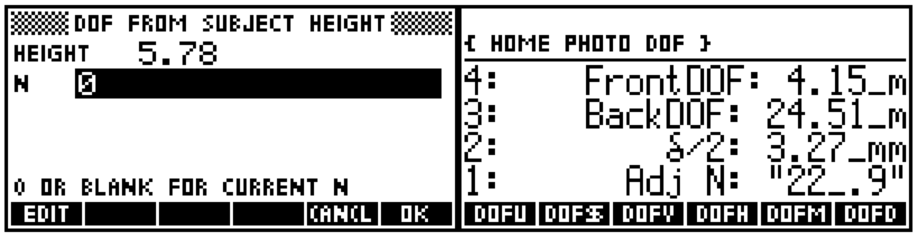
The distance between the lens and the film plane is v. It may be used to find DOF. Input and output for the DOFV program are shown below. As a sidelight, note that the adjusted N value is little different from the nominal N of 32. This is because the extension $215 - 210 = 5$ mm is very small relative to $F = 210$ mm. For close up work, however, the adjusted N will be considerably different. Suppose one were interested in a 1 to 1 image, then the 210 mm lens would have to be focused at 440 mm, and the adjusted N would become "11_9," and the DOF would shrink to about 11 mm.





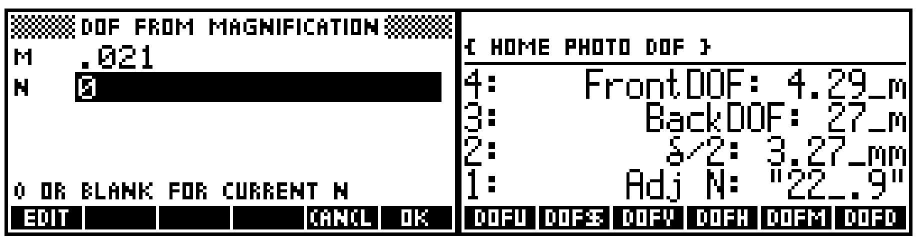
5.4 DOFH, From subject height

By subject height is meant the vertical extent of the subject which will fill the long side[8] of the image on the film. In the present case with $u = 10$ m, the height is 5.78 m. The input and output are shown for this value.



5.5 DOFM, From magnification

Magnification is the ratio v/u. In the present case it is $210/10000 = 0.021$ with both v and u in millimeters. Magnification is small for distant objects, but becomes large for close up photography. A magnification of 1 occurs when the image and subject heights are equal.



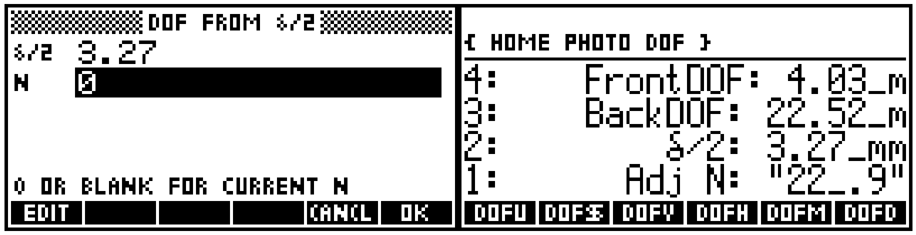
The output would have been slightly different had 0.02 been used for magnification. Whenever the output of two programs is unexpectedly different, look to the input values for an explanation. The calculations are done to many more places than are shown, and using too few places in the input can cause discrepancies.

5.6 DOFD, From defocus

The defocus, δ, is the distance along the rail between the cognates of the near and far DOF: i.e. the difference between the locations of the two standards when the lens is focused on each of the two DOF limits. This is illustrated in Figure (1). For practical purposes, it is symmetrical about v, the position of the rear standard when the subject is in focus. Using $\delta/2 = 3.27$ mm to be

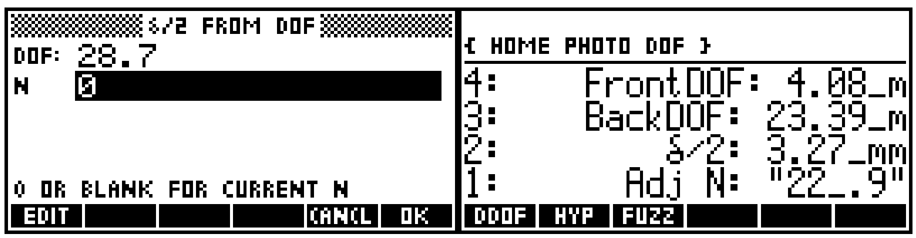
[8]The program chooses a film height of 124 mm for 4x5.

consistent with the previous examples, the input and output screens appear as:



5.7 DDOF, From depth of field

This program accepts the DOF. To be consistent with the previous examples, the DOF is set to 28.7 m.



5.8 HYP, Hyperfocal distance

This simply returns the hyperfocal distance for the global parameters.

The $\delta/2$ and adjusted N are different from the previous programs because u has changed from 10 m to the hyperfocal distance of 13.991 m.

5.9 FUZZ, Blurred images

Bokah is the Japanese term for out of focus or blurred objects. There is *good bokah* and *bad bokah*, but this is not the place to discuss its nature, and is only brought up here to introduce the fact that blurred images can form useful parts of a picture. Sometimes one has intrusive objects in the frame that need to be blurred, and sometimes it is just better to have a fuzzy area in a picture to support in a sense the main subject.

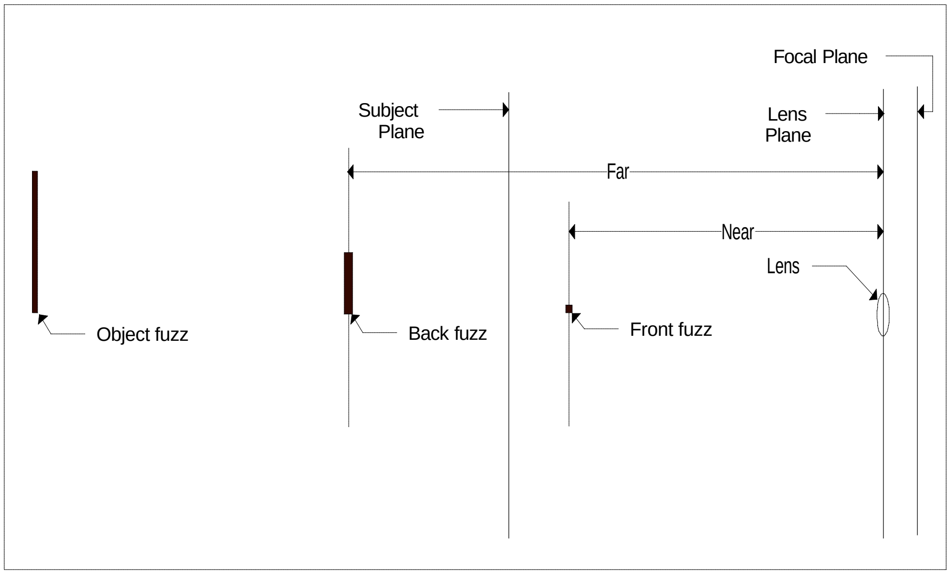
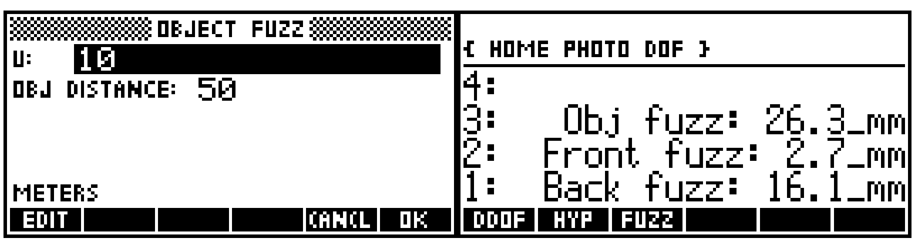


Figure 8: Fuzz at three distances

In any case, the FUZZ output shows the degree of blurring for objects at specific distances. FUZZ always calculates blurring values for the DOF limits, and in addition it will calculate them for a user input distance. Consistent with the above examples, suppose $u = 10$ m and let us suppose we need to know about an object at 50 m. Figure (8) shows the size of objects at three distances which image on the film at exactly twice the diameter of the circle of confusion. The input and output are:

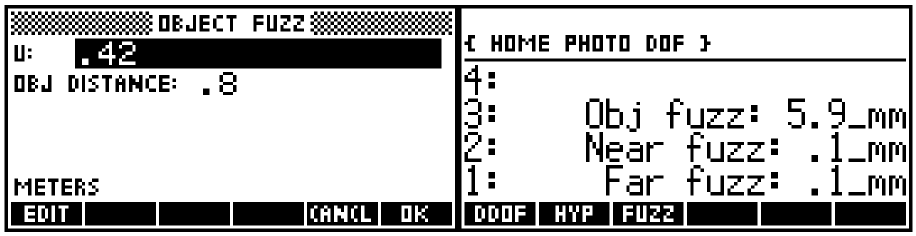


The *fuzz* values reported in the output, are the sizes of objects at the given distances which will image as twice the diameter of the circle of confusion[9]Thus objects at the Near DOF of size 2.7 mm will barely be distinguishable. Similarly, objects of size 16.1 mm at the Far DOF limit will not be distinguishable. At

[9]To find the size of an object which images k times the diameter of the circle of confusion, one should multiply the size, s, output by the program, by $k-1$. For $k=2$ the multiplier $k-1$ is 1, and this is s as output by the program. The size of the object imaging at four times the diameter of the circle of confusion would be $(k-1)s = 3s$. Using $4s$ instead, however, does little harm.

50m, a 26.3 mm object will not be distinguishable. This means that inch high lettering on an intrusive billboard some 50 m distant, will not be readable in a print. The lettering would have to be at four or more times this size to be readable, and even then would be very fuzzy.

This is especially useful for macro photography. Suppose you are photographing a flower at one-to-one magnification and there is an unavoidable object in the background. How visible will this object be? For a 210mm lens, one-to-one magnification puts the subject plane 420mm in front of the lens. Suppose the objectionable object is twice this far, say 800mm away from the lens. The FUZZ input and output are:



If the object is smaller than 5.9 mm, then it will not be visible. If it is larger, say 25mm, then it will be very fuzzy because its top edge will not be distinguishable from a line 1/4 of this distance down. The size of the object will thus correspond to about four times the circle of confusion on the film, clearly a negligible amount.

6 Finding the subject's height

By subject height is meant the height of the subject that just fills the long side of the film image. The ratio of the long side of the film to the height is the magnification[10]. The height may be calculated from any of several parameters. Five programs are provided. They and their parameters are shown in Table (2).

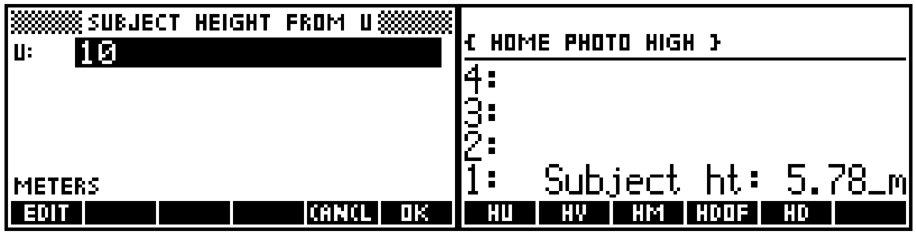
Program	Parameter
HU	u
HV	v
HM	magnification
HDOF	FrontDOF
HD	$\delta/2$

Table 2: Height program parameters

All input screens are similar, requiring a single parameter. Only the HU program will be illustrated. The output screen shows the subject height in

[10]Subject and film diagonals are often used instead of the height.

meters. The input and output screens are:

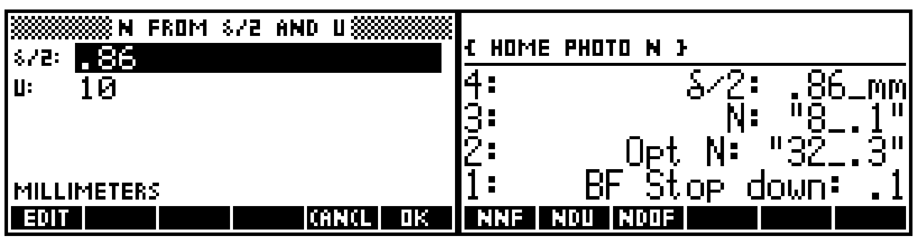


7 Finding the F-number, N

There are three programs, NNF, NDU, and NDOF, which calculate the F-number, N. For practical purposes, they may also be used with tilted lenses using magnification and distances measured horizontally through the lens center.

7.1 NDU, N from $\delta/2$ and u

The inputs are $\delta/2$ and u, as shown on the input screen at the left. The output is shown on the right, and if it is scrolled, one finds $u = 10$ mm.



The bellows correction shown at the bottom of the output depends only on the bellows extension and is thus the same for any N. It is given in stops, and may be subtracted from whatever N one selects. Thus "8_1" becomes "8_0" and "32_3" becomes "32_2."

Figure (9) illustrates the situation for the case when the lens is focused at infinity. In this figure, the optimum N line may be visualized as the crest of a mountain with the land sloping downward away from it. The "10 l/mm N" curve relates N to δ such that the on-film resolution is 10 l/mm. The "40 l/mm N" and "20 l/mm N" curves do the same for 40 l/mm and 20 l/mm respectively. The extent of the δ scale is appropriate for the 4x5 format. As a contrast, the dotted box at the lower left represents the δ scale appropriate for the 35 mm format. The reason that manufacturers choose $N = 16$ or $N = 22$ as the maximum F-number for 35 mm should be clear from this figure.

Should one use N or optimum N? It all depends on what is wanted. The output N corresponds to 10 l/mm, which is appropriate for an 8x10 print. The optimum N will of course support larger prints, but there seems little reason for choosing the optimum unless such large prints are the goal, and even then

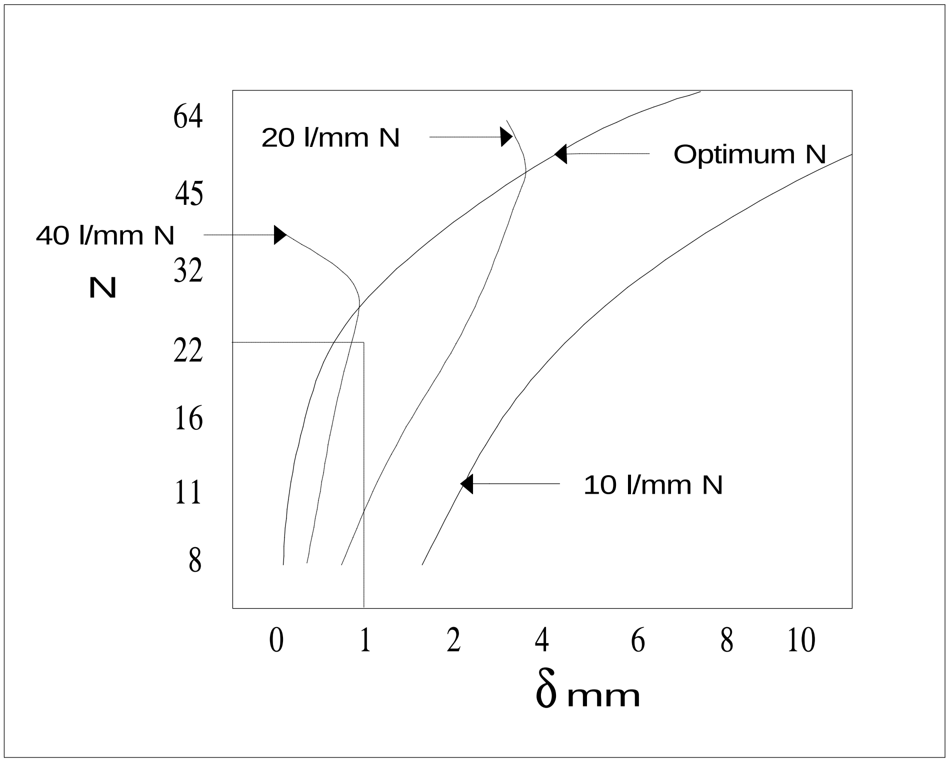


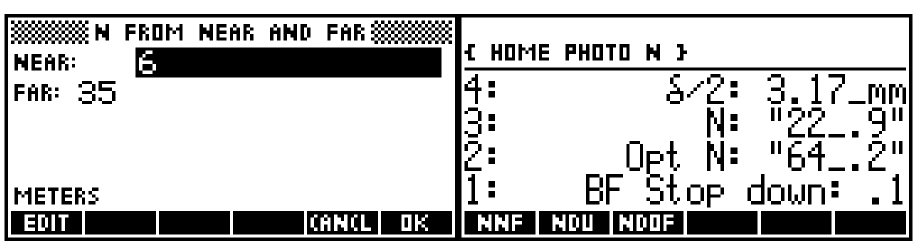
Figure 9: Optimum and resolution curves

as may be seen in Figure (9) the optimum N will be less than 20 l/mm for δ's greater than about four. The program RESL may be used to calculate the resolutions for particular combinations.

7.2 NNF, N from near and far values

NNF accepts Near and Far values for which it finds the N that will make them Near and Far DOF limits.

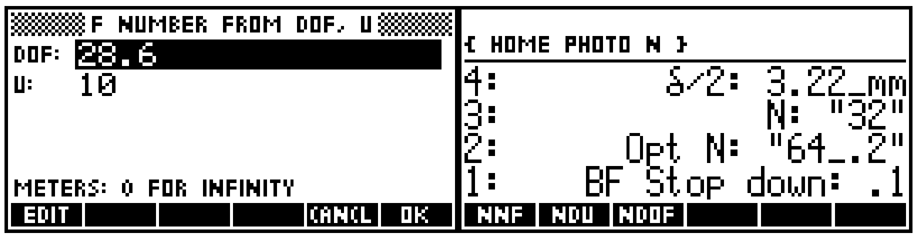
The input and output screens for NNF are as follows. Do not confuse the "Near" and "Far" values with "FrontDOF" and "BackDOF" values.



Scrolling up the output screen shows $u = 10.24$. The calculated N is about 32. In addition the N which produces maximum resolution is shown as the optimum N.

7.3 NDOF, N from DOF and u

NDOF accepts DOF and u, and finds N. The input screen is on the left, the output on the right.



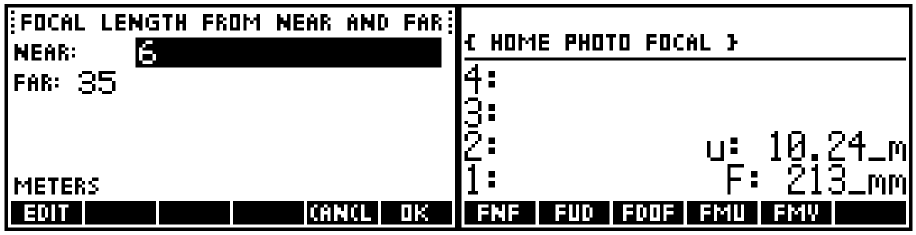
8 Finding the focal length

Focal length can be chosen in a variety of ways. The best way is to use a viewfinder to obtain a proper framing of the scene; however, other ways are possible. One may choose two distances, and map them into the DOF limits by a proper choice of focal length. Similarly, one may fix some other parameter, such as DOF or u, and calculate the focal length. Five programs are provided. They and their input parameters are show in Table (3). For practical purposes, they may also be used with tilted lenses using magnification and distances measured horizontally through the lens center.

Program	Parameters	
FNF	Near	Far
FUD	$\delta/2$	u
FDOF	DOF	magnification
FMU	u	magnification
FMV	v	magnification

Table 3: Focal length programs

The program FNF will be illustrated. The input and output screens are shown below. The F returned is the F required to make 6 m and 35 m the DOF limits.



9 Finding the magnification

Magnification is the ratio of the film size to the subject size[11], thus for a 2 m tall subject imaged on a 4x5 film with long side 124 mm, the magnification is $124/2000 = 0.062$. Magnification controls the appearance of a picture, in that the subject size will fill the same area of the film if the magnification is constant. A picture taken with a 210 mm lens will frame the same composition as one taken with a 600 mm lens if the magnification for the two is the same. For example, in the case of a 2 m tall subject taken with a 210 mm lens on a 4x5 camera, the subject must be 3.6 m away. For a 600 mm lens, the subject must be 10.2 m away. The UVM program may be used to confirm this.

Two pictures with the same magnification taken with different lenses may or may not appear identical – there can be a difference in resolution. The difference will be quite small, as may be seen by checking the DOFM program which produces the values in Table (4). The F-number in this table is $N = 32$ for both lenses.

Lens	Distance	FrontDOF	BackDOF
210 mm	3.6 m	0.71 m	1.17 m
600 mm	10.6 m	0.81 m	0.97 m

Table 4: Constant magnification for 2 m subject on a 4x5

Of course changing N will produce considerable differences in resolution, since DOF changes dramatically as N changes, but the point that has been made is that lens changes have little effect when magnification is constant.

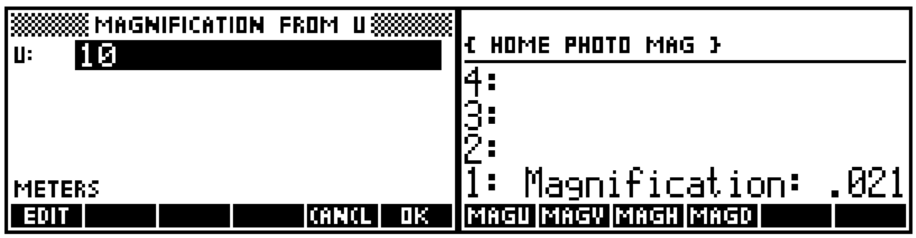
There are four programs for magnification, as shown in Table (5).

[11] Any film dimension may be chosen. Each dimension will produce a slightly different value. The long side of the image is chosen here. Magnification is also equal to v/u.

Program	Parameter
MAGU	u
MAGV	v
MAGH	height
MAGD	$\delta/2$

Table 5: Magnification program parameters

The input and output for MAGU is shown below:



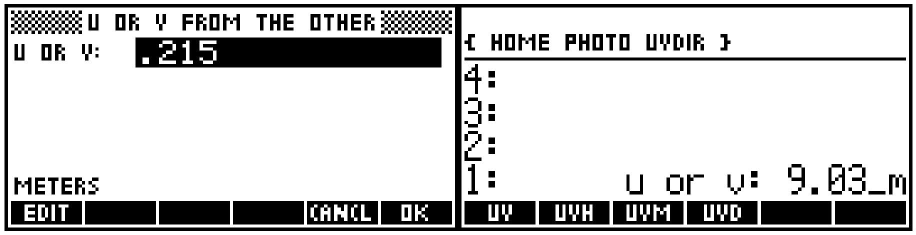
10 UV

The parameters u and v satisfy an equation called the lens equation, and one may be computed from the other. In addition, either may be obtained from other parameters. Four programs are given here. The UV program translates u into v or v into u. The others produce u and v from magnification, subject height, and $\delta/2$. The programs and their parameters are given in Table (6).

Program	Parameter
UV	u or v
UVH	height
UVM	magnification
UVD	$\delta/2$

Table 6: u and v program parameters

The input and output for UV with v as input are shown below. Note that the input must always be in meters.



11 Bellows Factor

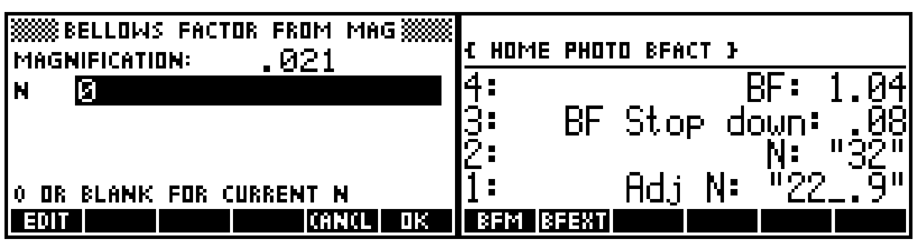
The F-number that is read from a light meter strictly applies to the situation when the lens is focused at infinity. When the focus point is closer to the the lens, the lens must be extended and this decreases the amount of light reaching the film by the inverse square law. That is if the lens is moved twice as far out, the exposure will be one quarter of the original. To compensate for this, one should multiply the shutter speed by a factor. The factor is called the "bellows factor." The programs in this section give the bellows factor as a function either of the magnification or of the lens extension. They also translate the bellows factor into stops so that one may adjust the F-number instead of the shutter speed if desired.

The programs and their parameters are given in Table (7).

Program	Parameter
BFM	magnification
BFEXT	extension

Table 7: bellows factor program parameters

The input and output for the BFM program are shown below.

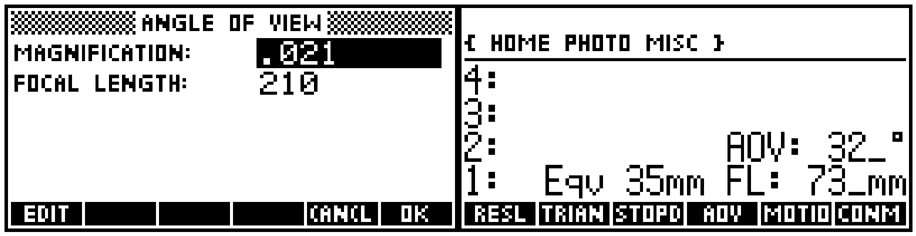


12 Miscellaneous programs

This section documents a number of miscellaneous programs such as AOV for finding the angle of view, and MOTIO for calculating the shutter speed required to stop motion.

12.1 AOV, from magnification and focal length

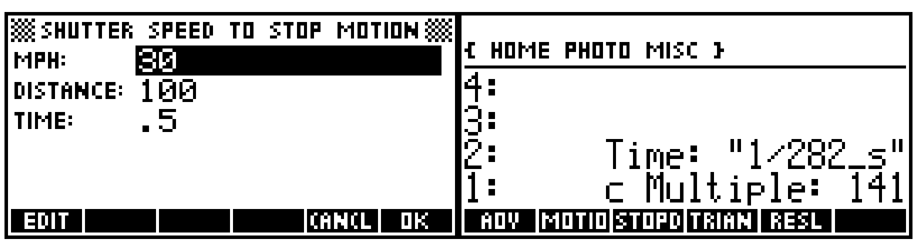
The input and output are as shown.



The last line of the output gives the focal length of a 35 mm lens with the angle of view shown.

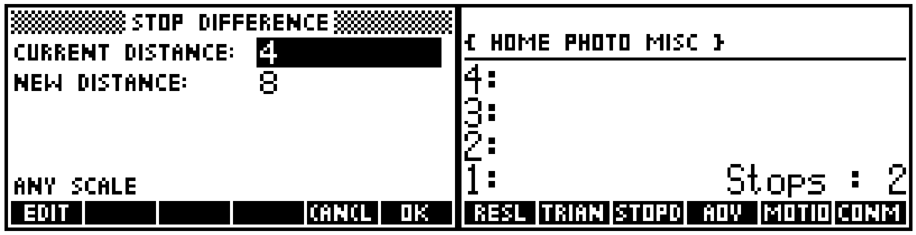
12.2 MOTIO, shutter speed to stop motion

The screen on the left shows input for a 30 mph hour object 100 meters away. The direction of motion is assumed to be at right angles to the lens axis. The output on the right indicates that a shutter speed of 1/282 seconds will stop this motion. One may not always be able to shoot at the indicated speed, and some idea of the degree of blurring is useful. If the desired shutter speed, in seconds is input, then the degree of blurr is shown on the output screen. The output gives the distance the image of the subject moves in units of c, the diameter of the circle of confusion. A time of 1/2 second was input on the screen on the left and the output screen shows that the image of a subject will cover a distance of 141 times c during the 1/2 second exposure. It will be very blury. As a rule a subject that moves only two or three times c may be acceptable.



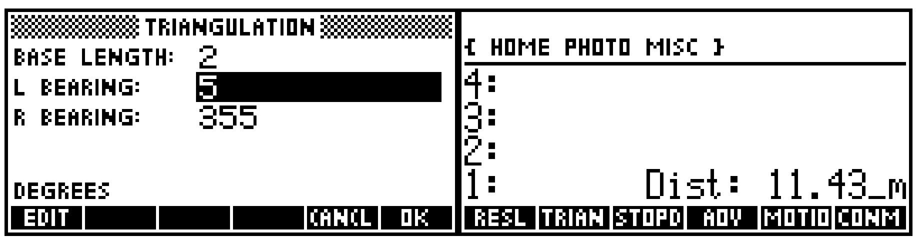
12.3 STOPD, stop difference for light movement

If the lights in a studio are moved, the F-number will change. This program gives the stop difference required to make the adjustment. On the left, the lights are at 4 m and they are to be moved to 8 m. The output on the right shows that the F-number must be increased by 2 stops.



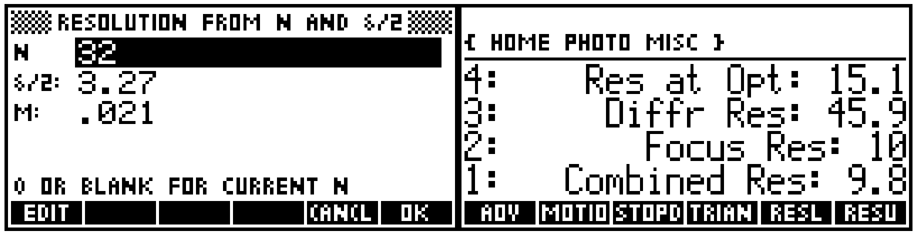
12.4 TRIAN, triangulation

The distance to an object may be found by triangulation. The input screen on the left requires the base distance and two compass readings. I generally choose a two meter base, since I carry a spring retraction pocket measure and it is easy for me to hook the end on the camera and move out one meter on each side. My compass is shown among the gadgets in Figure (2).



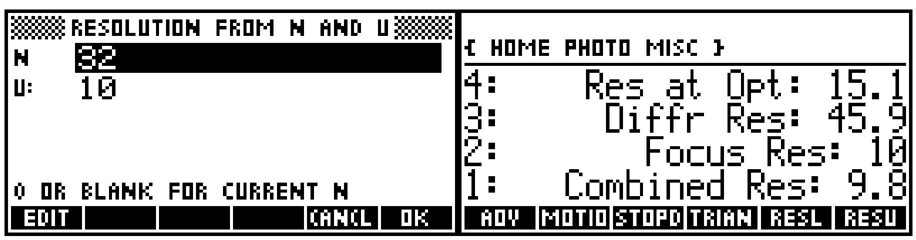
12.5 RESL, resolution

This is a theoretical calculation of no practical use in the field, but included for completeness. With it one may calculate the resolutions shown in Figure (9). On the left one sees the input screen with $\delta/2$ entered as 4. The output screen on the right shows the resolution at the optimum for $\delta/2 = 4$. Below this are the resolutions from two different sources which combine to produce the final resolution. The first of these is the diffraction resolution, and the second is the defocus resolution at a $\delta/2$ distance from the plane of exact focus. The two resolutions are combined using root mean square on their inverses – this is strictly an empirical combination since there is no simple theoretical way to combine them. It is interesting to note that the resolution due to diffraction is actually the largest resolution shown, which should give pause to those who ascribe poor quality to diffraction – in this case, the principal cause is extreme defocus.



12.6 RESU, at the DOF limits

Although diffraction is often thought of as an important source of image degradation, it is not in fact. This calculation shows the diffraction and defocus resolutions as was done in the previous subsection, but this time the resolutions are in terms of practical camera settings. The calculations are made at the DOF limits, which represent a worst case – resolutions for any distances closer to u than these DOF limits will be higher[12].It may be seen that for such practical settings, diffraction is always so much larger than defocus resolution, that it has little effect on the combined resolution. The maximum N engraved on a lens is chosen so that diffraction has an effect only in extreme cases. An extreme case would be one with N at the maximum and u just slightly larger than the focal length.



13 Technicalities

Parameters used by the programs are shown in Table (8). They may be changed if desired, but remember that they will be reset when one of the indicated programs is run.

[12]This may be checked using the previous program by decreasing $d/2$. The value of $d/2$ at the DOF limits may be obtained from any of the DOF programs.

Parameter	Set by	Explanation
Fδ	P	Focal length
Nδ	P	F-number
Cδ	P	diameter of the circle of confusion
DMδ	P	Film long side in mm
FSδ	P	Film size 35,645,67,69,45,810
$\gamma\delta$	Any tilt program	Slope of subject plane
Jδ	Any tilt program	Vert distance from lens to subject plane
$\theta\delta$	Any tilt program	Lens tilt angle
$\alpha\delta$	Any tilt program	Back tilt angle

Table 8: Parameters

BIBLIOGRAPHY

1. Bond, H. (1998). *Photo Techniques*, May/June

2. Merklinger, Harold, M. (1992) *The ins and outs of focus.* Ottawa, Canada.

3. Merklinger, Harold, M. (1993) *Focusing the view camera.* Ottawa, Canada.

4. Jacobson, R.E.; Ray, S.F.; and Attridge, G.G. (1988). *The manual of photography.* Eighth Ed. Focal Press, Boston.

5. bib:Kingslake) Kingslake, R. (1989) *A history of the photographic lens.* Academic Press, Boston.

6. Ray, Sidney F. (1994) *Photographic optics.* Focal Press, Boston.

7. Sears, F.W. (1958) *Optics*, Addison Wesley, Reading MA.

8. Stroebel, Leslie; Compton, John; Current, Ira; and Zakia, Richard. (1986) *Photographic materials and processes.* Focal Press, Boston.

9. Stroebel, Leslie. (1993). *View camera technique.* Focal Press, Boston.

Directory	Program Name	Page	Checksum	Description
	P	7	#4318d	Set and display parameters
VIEW				Viewframe information
	VIEWV	9	#11856d	u,FrontDOF,BackDOF from v
	VIEWU	10	#9427d	u,FrontDOF,BackDOF from u
TILT				Calculates tilt angle
	TILTB	12	#43025d	By back focusing
	TILTD	13	#52396d	From distances and angles
	TILTJ	14	#62975	From u and J
	TILTG	15	#63438d	From subject plane slope
DOF				Depth of field
	DOFU	16	#22354d	From u
	DOF$	17	#16249d	From ray angle, for tilted lens
	DOFV	19	#23592d	From v
	DOFH	20	#40427d	From height of the subject
	DOFM	20	#17139d	From magnification
	DOFD	20	#18561d	From $\delta/2$
	DDOF	21	#19545d	$\delta/2$ from DOF
	HYP	21	#40002d	The hyperfocal distance
	FUZZ	21	#40176d	Blurred subject size
HIGH				Subject height
	HU	23	#23625d	From u
	HV	23	#28437d	From v
	HM	23	#13283d	From magnification
	HDOF	23	#20163d	From DOF
	HD	23	#52578d	From $\delta/2$
N				Calculates F-numbers
	NNF	25	#40611	From near and far DOF limits
	NDU	24	#62842	From $\delta/2$ and u
	NDOF	26	#1200d	From DOF and u
FOCAL				Focal length
	FNF	26	#58387d	From near and far DOF limits
	FUD	26	#27295d	From $\delta/2$ and u
	FDOF	26	#31383d	From DOF and u
	FMU	26	#51068d	From DOF and magnification
	FMV	26	#43577d	From v and magnification
MAG				Magnification
	MAGU	27	#64906d	From u
	MAGV	27	#42492d	From v
	MAGH	27	#65288d	From subject height
	MAGD	27	#27241d	From $\delta/2$
UVDIR				u and v
	UV	28	#57029d	u to v or v to u
	UVH	28	#33989d	u and v from subject height
	UVM	28	#16880d	u and v from magnification
	UVD	28	#64295d	u and v from $\delta/2$
BFACT				Bellows factors
	BFM	29	#32060	From magnification and N
	BFEXT	29	#21325d	From extension and N
MISC				Various utilities
	AOV	30	#9063d	Angle of view from magnification and focal length
	MOTIO	30	#2351d	Shutter spread to stop motion
	STOPD	30	#31310d	Stop difference for two light distances
	TRIAN	31	#32858d	Triangulates to find subject distance
	RESL	31	#17469d	Theoretical resolution
	RESU	**??**	#47548	Resolution at the DOF limits