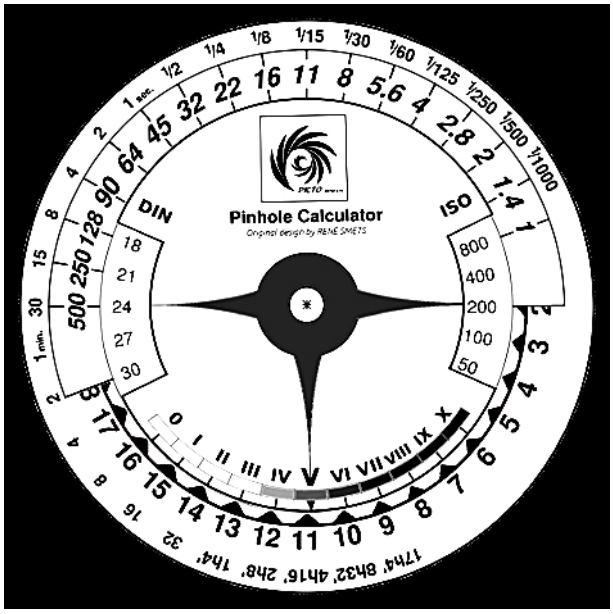
EXPOSURE TIMES
IN
PINHOLE PHOTOGRAPHY



René Smets – Jacques Kevers

March 2023

Foreword

For those who are familiar with pinhole photography, this document will probably not teach anything new. It has been written to help those who have built their own camera and are now wondering how to determine the correct exposure time for their shots.

But before delving into the technical details, it might be a good idea to ask oneself why getting involved in this kind of photography. The "Camera Obscura" page on the Picto Benelux website[1] is a good starting point for this.

This document will give you useful information to avoid some major initial disappointments and to obtain quickly and simply images of a quality that corresponds to your artistic objectives.

It will not present infallible recipes for achieving technically perfect images. If this is your goal, give yourself the means to achieve it by using top-of-the-range cameras and lenses, preferably using quality large format film...

Like traditional cameras, pinhole cameras are simply tools for creating an image. They can be used for playful, educational, social, artistic purposes, and their “rustic” character has allowed the development of a very particular aesthetic and philosophy, making a large place for serendipity – a somewhat barbaric term, little known outside the Anglo-Saxon sphere, which refers to the capacity to pay particular attention to the unforeseen, the unexpected, the surprises of the “providential misfires” in order to discover, to invent, to create, or to imagine something new without having specifically looked for it[2].

So don't believe blindly the countless articles published in bookshops or on the internet, claiming to guarantee a perfect image if one scrupulously follows their instructions for calculating the optimal diameter of the pinhole to the nearest $^{1}/_{100th}$ mm, or to determine to the nearest second the correction factor for the failure to the law of reciprocity (Schwarzschild Effect), inevitable with the usual long exposures this type of equipment requires.

Given the many uncertainties associated with the specificities of your pinhole box, the actual sensitivity of papers or films (sometimes outdated) which will change with their age, and the often incomplete nature of the information provided by manufacturers, nothing can replace the numerous tests required to develop your own know-how and experience.

And above all, don't forget: *Art loves chance, just as chance loves art*.[3]

J. Kevers

---

[1] - Picto Benelux : Pinhole Photography - https://www.picto.info/Etech03.html

[2] - De la Sérendipité, Leçons de l'inattendu – Pek Van Andel & Danièle Bourcier, Coll. Libres Sciences, L'ACT MEM, Chambéry 2009

[3] - Nicomachean Ethics, book VI, chap. 4 – Aristotle, french transl. J. Vilquin, Éd.Garnier-Flammarion, 1965, pp 156-157 (mentioned in “De la Sérendipité”)

Technical principles and definitions

Even if the technical rules mentioned above are not to be followed to the letter, it might be a good idea to familiarise yourself with the concepts on which they are based if you want to understand how this simple and practical tool – the **"Pinhole Calculator" –** works, and to use it properly.

The fact that it is very easy to use does not detract from its accuracy or its adherence to the basic optical principles, as with any commercially available analogue or digital light meter. It does not replace them, but complements them.

Exposure

A pinhole camera is a photographic camera. The degree of exposure of the light sensitive material therefore depends, as with any camera, on a combination of aperture and exposure time. But whereas for a camera with a lens both factors can be modified, the situation is different for a pinhole camera, since the aperture – a simple hole – is fixed. Therefore, you can only play with the exposure time. You will of course have to know the diameter of the pinhole, if you want to adjust the exposure in a way that does not rely on simple chance only or on your own experience, acquired from your previous (many of them unsuccessful) attempts .

This diameter is normally known. If not, it can be measured with the help of a slide projector or a scanner. With the diameter and the focal length (distance from the pinhole to the sensitive surface), one can calculate the relative aperture of the camera. There are formulas or calculators for this, which can be found on the Picto website, among others.

This being said, there are basically three ways of choosing an exposure time:

1 - Guessing. It is perfectly possible to open the shutter for a period of time by trusting your intuition. If it appears during development that the negative is over- or underexposed, it will be necessary to start again by modifying the exposure time, as many times as necessary to arrive at a result considered satisfactory. Over time, the experience gained will allow the number of attempts to be reduced, but it is certain that at the beginning, time, products and paper (film) will be wasted. On the other hand, you don't have to bother with light meters or other calculations...

2 - The "f/16 Rule" (also called "Sunny /16 Rule"). This is a method of estimating aperture and shutter speed parameters according to the light situation, without any tools. This "rule" states that on a sunny day, the correct exposure time will be the inverse of the sensitive material's ISO value with the aperture being set at f/16. From this we can deduce the f-stops/5.6 for a very overcast sky - f/4 for a sunset - f/22 for a sunny snowy landscape.

So for taking a picture on a sunny day, using an ISO 100 film, it is likely that by choosing an aperture of f16, and an exposure time of 1/100s, my negative should be correctly exposed.

The rule is easy to remember, but it requires that you are able to correctly evaluate the luminosity of the moment. Moreover, as the pinhole box does not allow you to modify the aperture, you will have to make a calculation to find the exposure time corresponding to the aperture you have...

3 - Using a light meter. There is nothing to prevent you from proceeding as for any other shooting, using a light meter (hand-held, of course, as our box does not have a built-in cell). There are, however, two complications that must be taken into account. If the sensitive surface is photographic paper, its sensitivity must be assessed. This information is rarely given by the manufacturer, and one will often use more or less "old" (if not out of date) paper whose sensitivity will have evolved with time. Generally, a sensitivity between 2 and 6 ISO will give good results.

Moreover, if the majority of light meters are able to handle such low sensitivities, their aperture scale does often not allow to reach the usually very high values of pinhole camera apertures. Here again, you will have to make a calculation...

*It is precisely to avoid having to make these calculations at the time of shooting that we propose a small tool, simple to use and easy to carry: the "**Pinhole Calculator**".*

Of course, there are spreadsheets that can be used to obtain the desired result from a computer, but who is going to carry a laptop in addition to his photo equipment? One could also do the calculations at home and print a table with the exposure times corresponding to those measured when the aperture is set to f/16 – except that, if one has several pinhole cameras with different apertures (the latter being a function of the focal length), one would need as many different tables..
The "**Pinhole Calculator**" proposed below can be adapted to all situations, except one: it does not take into account the particular behaviour of photosensitive surfaces in the case of very long exposures (Scharzschild effect). See below for more info on this.

One final thought, however. As said in the foreword, technical perfection is not always the most important objective pursued by the "pinhole photographer" who may consider that some imperfections are not very important, or even do add a charm to the image (a bit like collodion prints). The experimental and playful character of pinhole photography is precisely what brings many photographers to this technique... It will be up to each one to decide what he expects from it.

Zone System

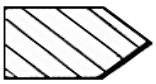
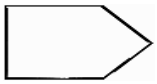
This system was developed by Ansel Adams and Fred Archer around 1939-1940. Our aim here is not to explain it in detail, but to summarise its logic, and to explain quickly what the marks from 0 to X (in Roman numerals) on the calculator presented below correspond to.
Many books have been written on the Zone System, many of which are frankly difficult to access and quickly discourage their readers. This has given the system the reputation of being a complicated technique applicable only to large format photography, requiring advanced knowledge of sensitometry, being reserved for densitometer maniacs obsessed with technique and curves, and spending more time testing than taking photographs. This is to forget that the first version of the system taught by Adams and White was mainly empirical and did not use sophisticated tools. Moreover, Ansel Adams used very often the 120 format, and was convinced that even small format film could benefit from it.

The Zone System allows you to relate the different luminances of a subject to different grey values, ranging from black to white, that you would like to assign to each of these luminances in the final image.

The luminance measurement of the subject is done by means of a light meter. All light meters are made in such a way that if you take a measurement on a surface and use the indicated exposure settings as they are, that surface will be rendered as a medium grey. This average grey corresponds to what Ansel called "Zone V" in a scale of 11 zones from 0 to X, to which correspond grey values ranging from pure white to absolute black. The Roman numerals on our calculator correspond to these zones.

More concretely, these areas could be defined as follows:

ZONE 0		There is no density in the negative, except of course for the density given by the film base and the base fog after development. Total black without any detail in the print
ZONE I		The first threshold of sensitivity, the first step above complete black on the print. The first slight separation of tones, but without any structure.
ZONE II		A first (very slight) suggestion of structure; very dark tones corresponding to the darkest parts of the image where some detail is needed.

ZONE III		Quite dark material; the corresponding values have a texture suitable for printing.
ZONE IV		Medium-dark foliage, dark stones, shadows in a landscape. Normal shadow value for portraits of Caucasian skin in sunlight.
ZONE V		Medium grey (18% reflectance). Clear northern sky as rendered by panchromatic film, dark skin, grey stone, average wheathered wood.
ZONE VI		Average value of Caucasian skin in sunlight, natural or artificial diffuse light. Clear stone, shadows on snow in sunny landscapes, clear northern sky as rendered on panchromatic film with light blue filter.
ZONE VII		Very light skin. Light grey subjects. Snow under bright side light. The lightest tonal category that still gives a very good rendering of the texture.
ZONE VIII		Whites with texture and delicate values; textured snow; Caucasian skin highlights.
ZONE IX		White without texture, approaching pure white, thus comparable to zone I in its light tone without real texture. Snow under flat light. With small format negatives printed with a condenser enlarger, zone IX is rendered as a pure white indistinguishable from zone X.
ZONE X		Pure white photographic paper; specular reflections or light sources in the image.

Various controls, at the time of shooting and/or during the processing of the negative, make it possible to shift the values measured by the light meter; certain values are said to be “placed” in a zone of one's choice. This makes it possible to obtain a more realistic reproduction and to express one's own predefined vision by assigning adequate grey values to the final print. The aim is to obtain the optimal negative allowing the final print to be made as easily as possible on normal contrast paper, which is the most able to faithfully reflect all the tones of the negative.

These indications on our calculator are not of primary importance and can be ignored. They have been retained because they appear on a number of light meters, and can be a telling guide for those who are familiar with this categorisation.

IL – EV -LW

On our “**Pinhole Calculator**”, the numbers with a small black triangle, just below the Roman numerals of the zones mentioned above, correspond to the Exposure Values (EV), (in German, Lichtwert - LW). These values can be found on most hand-held cameras, as for example here on the Gossen Profisix SBC.

These numbers characterise the various time/aperture combinations to achieve a given exposure. The EV scale thus represents a set of light levels. The more light there is, the higher the index. A change of 1 EV corresponds to a doubling or halving of the light level (with a constant aperture, the exposure time is halved or multiplied when the index changes by one; with a constant exposure time, the aperture must be opened or closed by one stop for the same change).

The EV value “0” corresponds to an aperture of f/1.0 combined with an exposure time of 1 second at ISO 100.

The table below gives a concrete example of these combinations. It could of course be extended to values not shown here

Exposure time in seconds or minutes (min) depending on the light value and relative aperture										
EV T	**1.0**	**1.4**	**2**	**2.8**	**4**	**5.6**	**8**	**11**	**16**	**22**
0	1 s.	2 s.	4 s.	8 s.	15 s.	30 s.	60 s.	2 min.	4 min.	8 min.
1	1/2 s.	1 s.	2 s.	4 s.	8 s.	15 s.	30 s.	60 s.	2 min.	4 min.
2	1/4 s.	1/2 s.	1 s.	2 s.	4 s.	8 s.	15 s.	30 s.	60 s.	2 min.
3	1/8 s.	1/4 s.	1/2 s.	1 s.	2 s.	4 s.	8 s.	15 s.	30 s.	60 s.
4	1/15 s.	1/8 s.	1/4 s.	1/2 s.	1 s.	2 s.	4 s.	8 s.	15 s.	30 s.
5	1/30 s.	1/15 s.	1/8 s.	1/4 s.	1/2 s.	1 s.	2 s.	4 s.	8 s.	15 s.

source : https://fr.wikibooks.org/wiki/Photographie/Mesure de la lumière, posemètres/Indices de lumination

Although in theory this scale can be extended as far as one wishes, there are hardly any light meters that show values above 18-19, because there are hardly any light levels above these values in nature.

The presence of these Exposure Values on a light meter makes it easy to modify the exposure settings from what is recommended by the meter, with respect to the specific shooting conditions and the tonal value that one wishes to attribute to a particular image component. However, it should be borne in mind that if a given EV corresponds to a whole series of time / aperture pairs which will all give the same level of illumination, the choice of a particular pair will have significant aesthetic effects: depth of field, motion blur, etc... This aspect is irrelevant in pinhole photography, since the aperture is fixed, and the necessarily long exposure times do not allow to “freeze” the movement.

The distribution of the numbers on the different discs of our calculator is such that a change of the ISO (Din) values automatically adapts the EV values to this new sensitivity. In addition, the juxtaposition of the EV values and the zone indications makes it possible to get very intuitively a sense of the effect the correction will have (darker, lighter..).

Schwarzschild Effect

The term reciprocity in photography refers to the fact that an exposure of $^1/_{500th}$ of a second with an aperture of f/2.8 will be equivalent to an exposure of 4 seconds with an aperture of f/128. Yes, but ... this is not always the case! For today's film, reciprocity works well for exposure times between 1sec and $^1/_{1000th}$ approximately.

Karl Siegmund Schwarzschild, a German astrophysicist, developed a formula defining the evolution of a photosensitive surfaces' sensitivity as a function of exposure time and illumination, highlighting the fact that the more a surface is exposed, the less it reacts to an additional dose of light (this phenomenon thus highlights a reciprocity defect, better known as the “Schwarzschild Effect”).

As in pinhole photography, we are more than often led to use exposure times of several seconds, minutes or even hours, this reciprocity defect is affecting us directly, and we will have to apply quite often a correction factor to the exposure time given by our light meters, and thus also by our “**Pinhole Calculator**”.

This could easily be done by playing with the Exposure Values. Except that not all photosensitive surfaces react in the same way to the Schwarzschild Effect, and that the film manufacturers' technical documentation is often limited to information for an exposure range that is far too narrow for our needs. But it's better than nothing... For photographic papers, it's worse: the information is often missing.

For the use of B&W photographic paper, the following table could be used as a guideline. Guillermo Peñate, a pinhole specialist, summarised his personal experiences in it. The first line represents the estimated or measured time, the second line the correction factor to be applied.

"Schwarzschild effect" for B&W photographic papers.									
1sec.	5 sec.	10 sec.	25 sec.	40 sec.	1 min.	2 min.	5 min.	10 min	20 min.
x 1,25	x 1,5	x 1,75	x 2	x 2,4	x 2,75	x 3	x 4	x 5	x 6

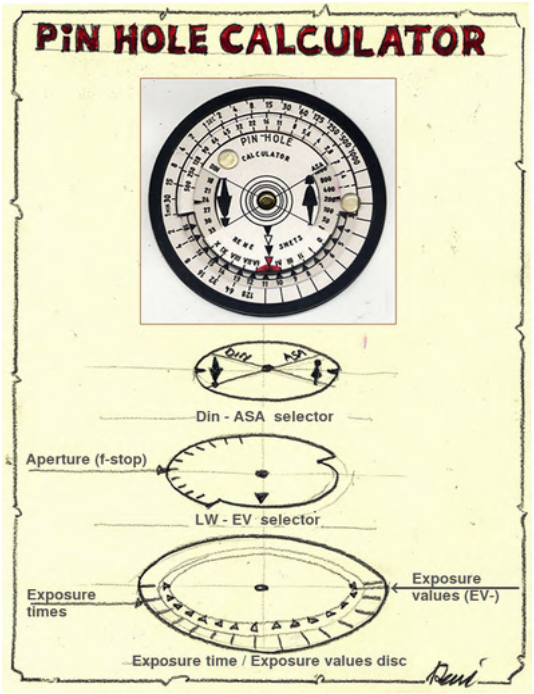
Source : Determining Pinhole Size and Exposure - Guillermo Peñate

So if a metering gives an exposure time of 10 minutes, it would have to be multiplied by 5, resulting in an effective exposure time of... 50 minutes.
Hopefully, during this time, clouds won't appear in the sky, or the light won't diminish too much due to the late hour.

As you can see, all light meters or calculators, however sophisticated and ingenious they may be, find their limits in pinhole photography. Does this mean that they are useless? No! they will provide a good starting point, and probably directly exploitable results in the less extreme cases. But in the other, a good dose of experience, and probably a lot of failed attempts at the beginning, will be necessary. Perseverance will allow to master all the parameters. And the "**Pinhole Calculator**", although it cannot guarantee a foolproof solution, will nevertheless make life easier.

Considering all of the above, it appears clearly that it is not absolutely required to calculate the Schwarzschild effect to the second. Nothing will surpass practice!

An aid for calculating exposure times: the "Pinhole Calculator"



A René Smets creation

René Smets, co-founding member of Picto Benelux, makes cameras, including pinhole cameras. And of course he uses them. He designed this little accessory that makes his life much easier.

Let's say it right away: the proposed calculator is not the only one of its kind. A little research on the internet will allow you to find others, very similar. It is based on the dial found on the old Pentax spotmeters (see below, left).

It is composed of three discs, with, from bottom to top :

1- bottom disc: outside exposure times, inside Exposure Values

2- middle disc: f-stops on the outside, ISO and Din values on the inside

3- top disc : Zone System Roman numerals, which are not strictly required here

Its main characteristics :

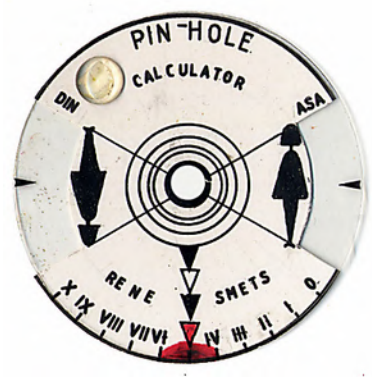
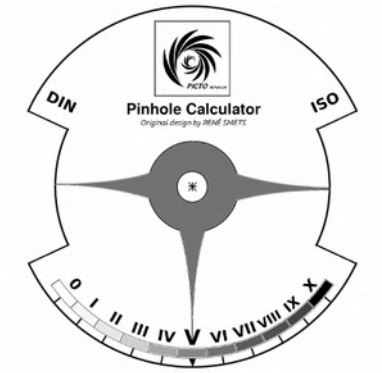
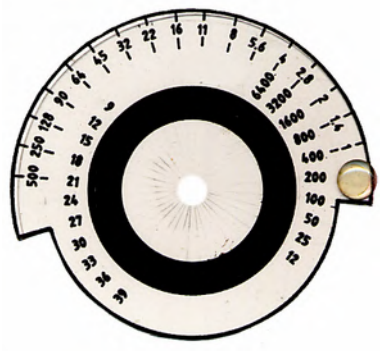
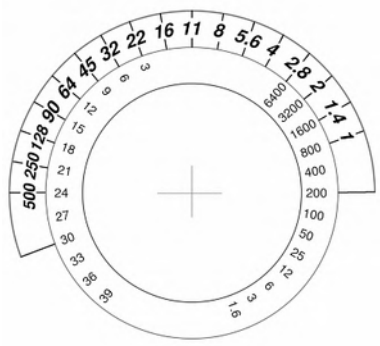
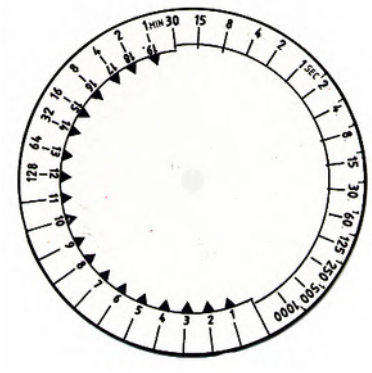
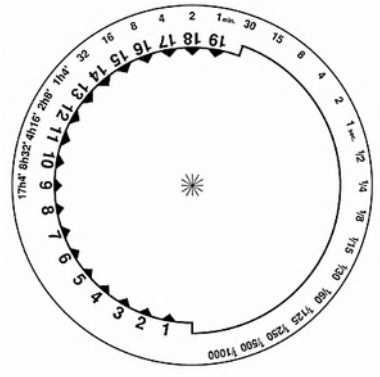
- The extended aperture scale will fit most pinhole cameras
- Small (8.5 cm.), fits easily into a bag.
- Slightly larger than the dials on most light meters, it is easily readable
- Exposure Values improve readability and make it easier to use

A Picto Benelux adaptation

In agreement with the designer, Picto Benelux has made an adaptation based on the original sketches. Those interested just have to print, cut out and assemble the parts they find at the end of this document to obtain their own personal calculator. It is of course up to them to choose a light but solid support on which they will glue the different discs – as well as the assembly system that will also serve as a pivot.

The adaptations made are merely cosmetic, with the exception of the following: whereas René Smets designed his calculator to give an overexposure of one f-stop – which suited his exposure and development technique – it was preferred in this version to stick to the "official" correspondence of Exposure Values with illumination levels and to leave the choice of any corrections to the users. In addition, the scale of exposure times has been extended, with the longest times being expressed in hours.

Below is a comparison of the original sketches and their adaptations

<table>
<tr>
<td> 
</td>
<td> 
</td>
</tr>
<tr>
<td>  </td>
<td>  </td>
</tr>
<tr>
<td>  </td>
<td>  </td>
</tr>
</table>

Instructions for use

On the calculator, select the “speed” of the film/paper used. For photo paper, it is generally considered that its sensitivity is between ISO 6 and 2. René Smets generally adopts a value of ISO 9. This sensitivity also varies with the age of the paper.

Using your light meter, measure the brightness of the scene. Note the corresponding EV-value.

Go back to the calculator and turn the middle disc so that the arrow (and corresponding V Zone) is aligned with the measured EV-value. If your light meter is not displaying EV's, find an aperture/time pair, and set the calculator with the same. If you are just estimating the light level, with or without the help of the "f/16 rule", use the aperture/time pair of your choice.

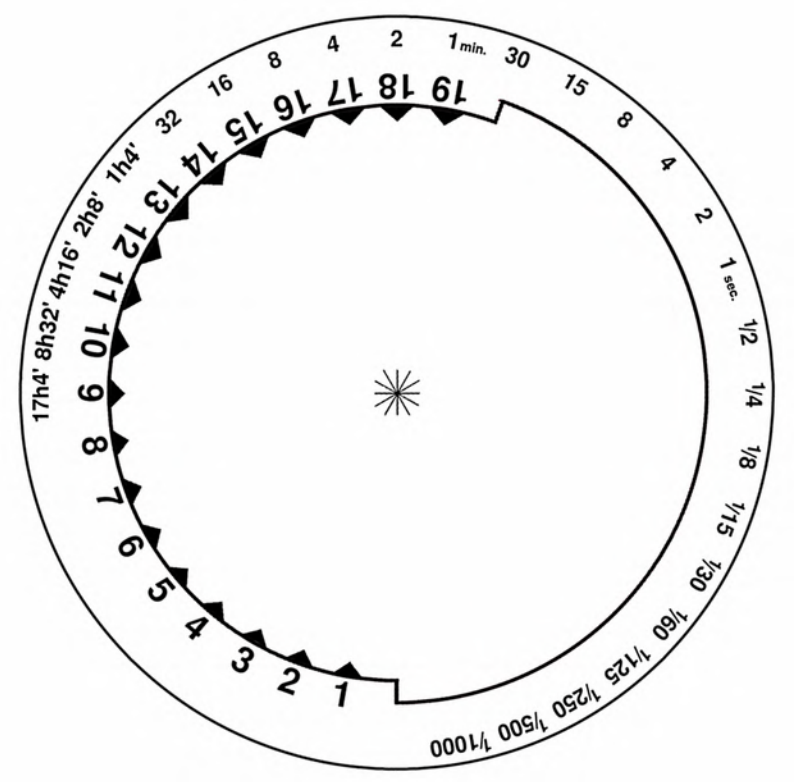
Then find the aperture of your pinhole camera on the disc (*if you don't know it, you will have to calculate it on beforehand, see the Picto website for more details: : https://www.picto.info/pinholdoc/pinholcalc.xls and https://www.picto.info/pinholdoc/PINformules_e.pdf*) and read the exposure time that corresponds to it. It is not more complicated than that...

Build your personal calculator

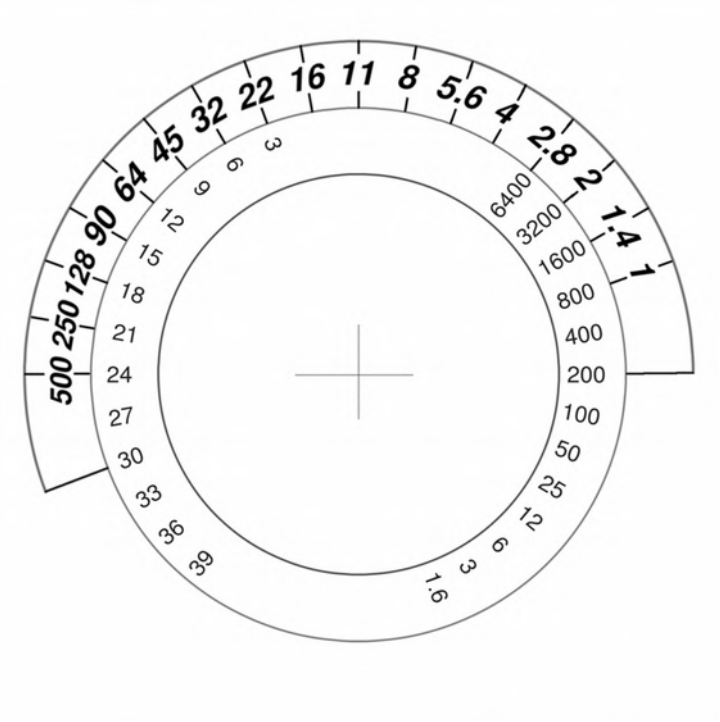
Below, you will find the drawings of the different discs. All you have to do is to print them out, cut them out, glue them on a light but solid support (cardboard, plastic, aluminium...), drill all the discs in the middle and use the system of your choice to hold the discs together, while allowing them to rotate… The drawings are calibrated so that the discs will fit exactly with each other and give you a calculator with a diameter of 9,5 cm.
If the size of the discs does not suit you, you can download the original files here (.tiff , 600px/inch) and adjust the size to your liking by changing the resolution.

Have fun !

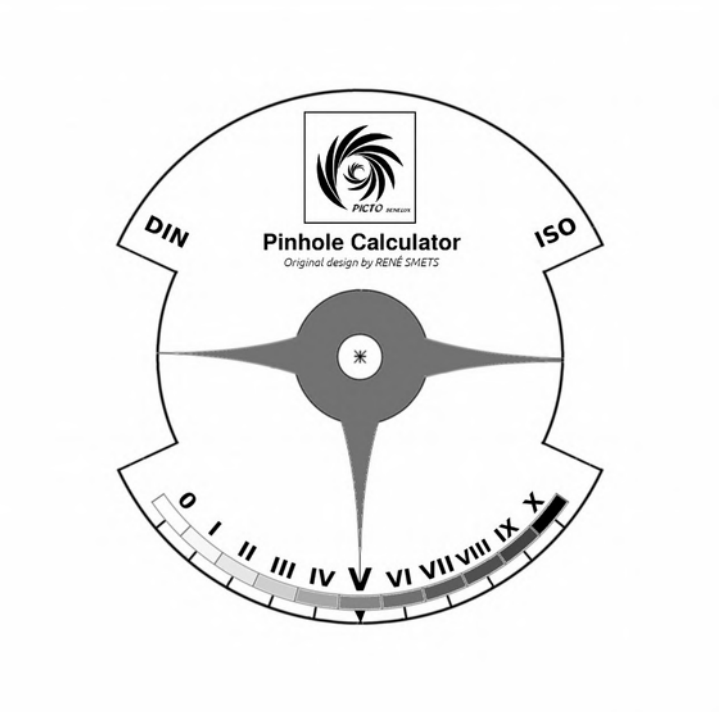
Bottom Disc



Middle Disc



Top Disc



Picto Benelux is an informal group, open to anyone in the Benelux who is actively interested in the processes developed and practiced since the origins of photography. The aim is to revisit them, while respecting each other's creative approaches.

https://www.picto.info/

Contact: Jacques Kevers - jacques@kevers.org