Pinhole camera project

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2021

1 Purpose

In this small personal project, I set out to build a functional *pinhole camera*. A pinhole camera captures images without the use of a lens: instead, light enters through a very small aperture, which—if properly sized—produces surprisingly sharp and detailed photographs. While the concept dates back to early optical studies, it remains a powerful example of how simple geometry and physics can produce an image.

My goal was not only to take a photograph, but to reproduce the entire analog process from scratch: building the camera, exposing the film, developing it chemically, and finally printing the image on paper.

2 Film Format

Among traditional film formats, the 35 mm is by far the most common. Although convenient and portable, it presents several engineering challenges for a hand–built pinhole camera: the film transport mechanism must be precise, the camera body must be compact and accurately aligned, and the resulting negatives are small, requiring optical enlargement during printing.

Since my objective was to study the process rather than maximize the number of exposures, I opted for a large–format film, specifically the smallest of the "large formats": the 5×7 inch (13×18 cm) plate. This format offers several advantages: a larger negative area, finer image detail, and the possibility to make direct contact prints without an enlarger. After researching several options, I purchased a standard film holder (also called with the french name *chassis*) for about 20 $, which provided both a working reference and a useful template for future self–construction.

3 Camera Design

Structurally, a pinhole camera is a light–tight box with a film plane on one side and a small aperture on the opposite side. I decided to build mine in wood, allowing for modular modifications later on, such as interchangeable pinhole plates.

The key design parameter is the focal length f, the distance between the aperture and the film plane. This value determines the field of view: shorter focal lengths correspond to wider field of views.

In my case, I was interested in wide-angle photography, so I focused on relatively low values of f. It's important to keep in mind that there's obviously a limit to how small f can be, since light rays reaching the edges of the film travel a longer path than those perpendicular to it.

Between a full-frame and the selected large format, there's a crop factor of about 5. So I'd say that choosing $f = 10$ mm for a full-frame sensor, which corresponds to about $f = 50$ mm for my pinhole, is an excellent choice. This gives me a wide-angle view, a relatively small pinhole, and moderate vignetting.

4 Aperture Optimization

The optimal pinhole diameter can be estimated by minimizing diffraction and geometric blur. Following the classical Rayleigh formula:

$$d = 1.41\sqrt{f\,\lambda} \tag{1}$$

where λ is the wavelength of visible light (typically $550\,\mathrm{nm}$). For $f = 50$ mm, this gives an ideal diameter of approximately $d = 0.3\,\mathrm{mm}$.

The hole was made by gently piercing a thin sheet of aluminum with a fine sewing needle, then polishing it to remove burrs and ensure circularity.

With these value, I get an f-number of:

$$\text{f-number} = \frac{f}{d} = \frac{50}{0.3} = 167 \tag{2}$$

5 Film and exposure

I chose the cheapest films I could find on the market, the Fomapan 100 ISO. With the current f-number value, the reciprocity law no longer holds, and the Schwarzschild effect occurs, as shown in the table below. Typically, on a sunny day, an optimal exposure lasts about 4 minutes.

	1/1000–1/2 s	**1 s**	**10 s**	**100 s**
Lengthening of exposure	1x	2x	8x	16x
Correction of aperture number	0	-1	-3	-4

Table 1: Schwarzschild effect for the fomapam 100 ISO: correction factors for long exposures.

Figure 1: Left: Back of the assembled pinhole camera, showing the black-painted interior and the interchangeable aluminum foil mount with the pinhole. Center: Back of the assembled pinhole camera with the holder inserted. Right: Front of the assembled pinhole camera with a manual shutter featuring magnetically fixed positions.

6 Film Development with Caffenol

For developing the exposed film, I chose to experiment with Caffenol, a homemade developer composed of instant coffee (as a reducing agent), sodium carbonate (as an alkali), and vitamin C (as an accelerator). This eco–friendly solution replaces conventional silver–based developers and is ideal for small–scale experimentation.

The development was carried out in a makeshift darkroom (a light–sealed bathroom), maintaining the solution at a constant 20 °C with gentle agitation. After several tests, I obtained negatives with satisfactory tonal contrast and fine grain, as shown in Figure 2.

7 Printing with Cyanotype

For the final print, I employed the cyanotype technique, one of the earliest photographic printing processes. Rather than using pre–mixed solutions, I prepared the chemicals (ferric ammonium citrate and potassium ferricyanide) from powdered reagents, mixing them in equal parts immediately before coating.

The photosensitive solution was brushed onto 180 g/m^2 watercolor paper and dried in the dark. The contact print was made by exposing the negative under direct sunlight for about 13 minutes, then rinsed with water and treated

Figure 2: Developed negatives using the Caffenol process.

with hydrogen peroxide to enhance the deep blue tone. Drying occurred in a dark, dust–free environment for 12 hours. Final result is shown in Figure 3.

8 Conclusion

This project successfully reproduced the complete analog photographic workflow—from camera design to chemical printing—using minimal and accessible materials. The experience provided valuable insights into optical geometry, material tolerances, and photographic chemistry. Beyond the technical outcome, building a pinhole camera reaffirmed a fundamental principle: even the simplest optical system, when carefully designed and executed, can capture the world with remarkable fidelity.

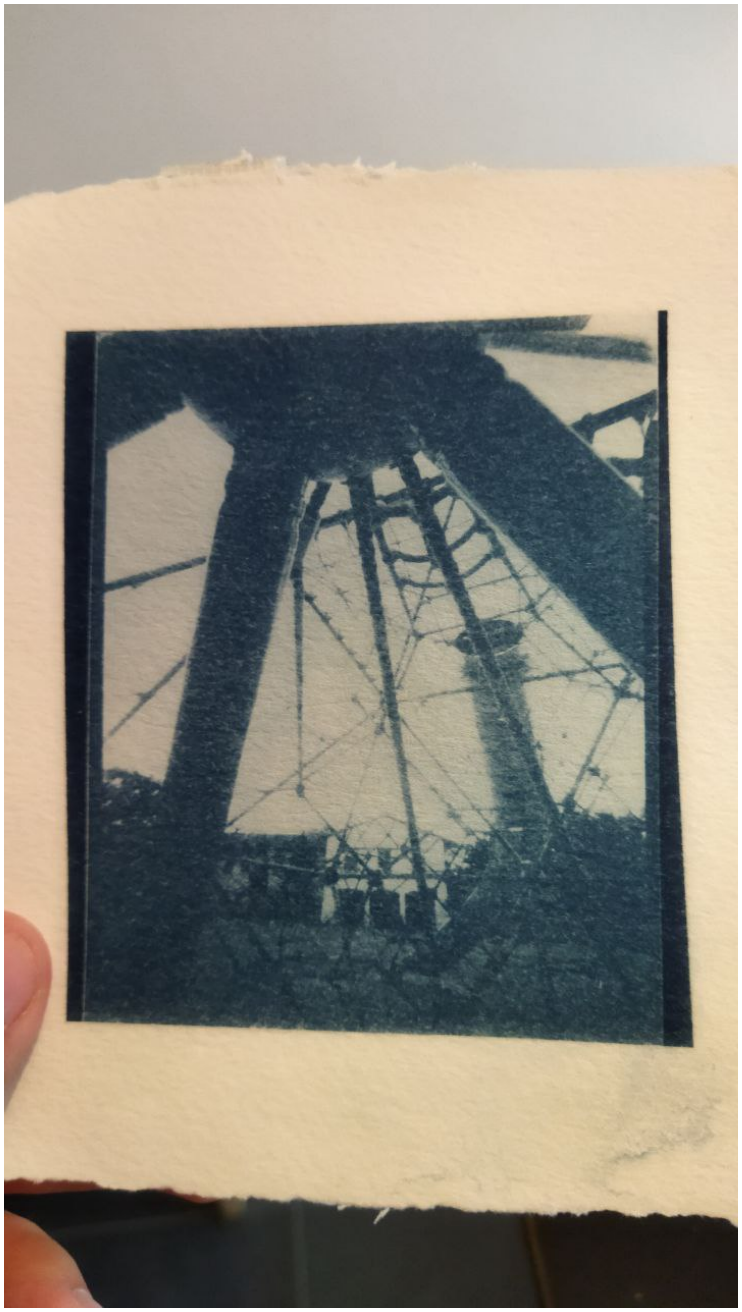

Figure 3: Final cyanotype print exposed under sunlight in Geneva (Switzerland) on August 21, 2021, 11:30 AM. The image depicts a children's playground slide.