# Perceptual Optics — 1. What Does a Pinhole Do?

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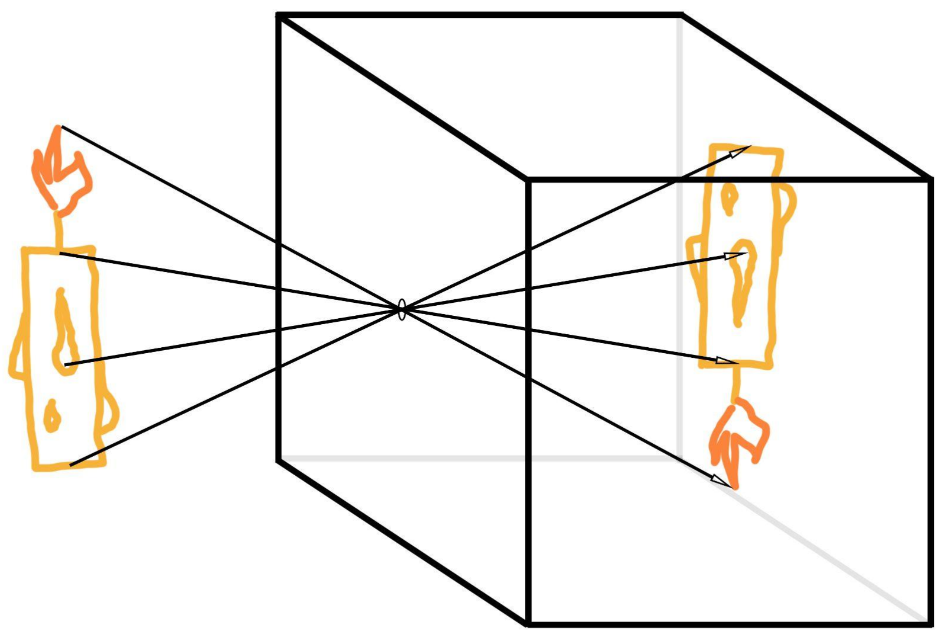
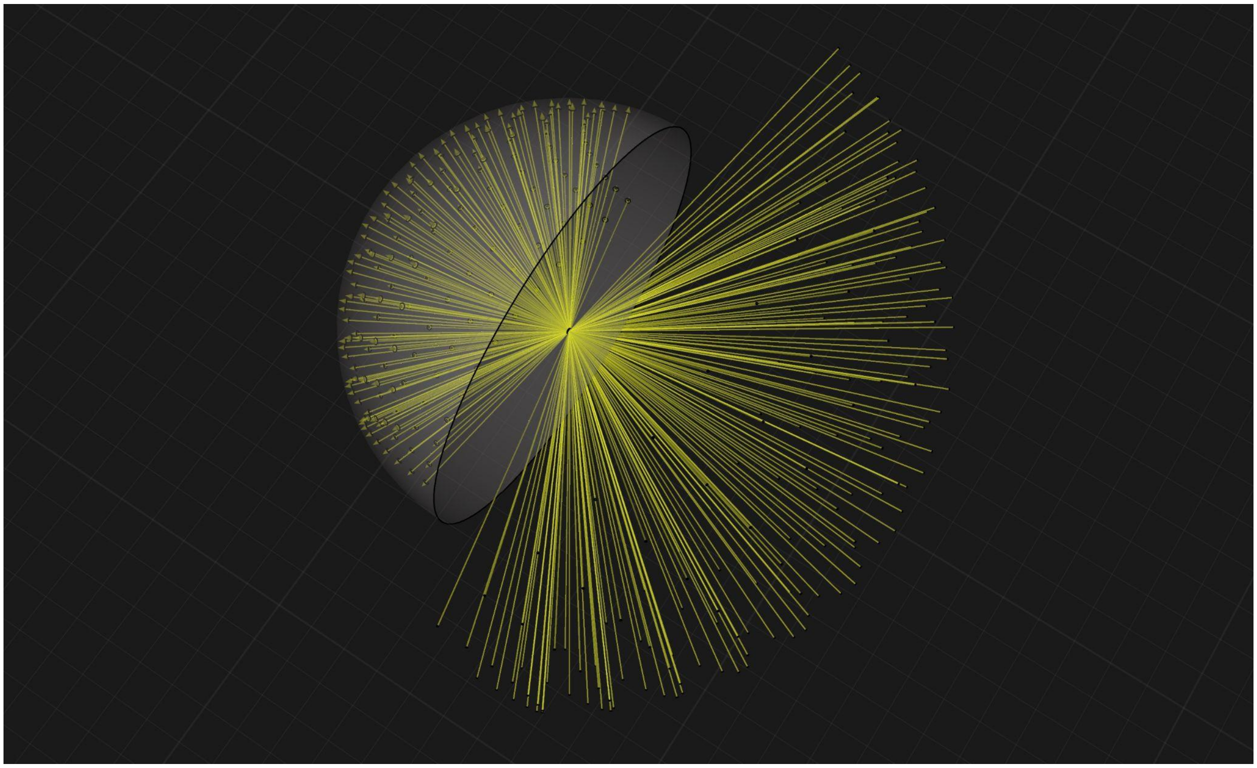
The **pinhole** is the starting point for understanding cameras, eyes, and visual perception. It forces one to exclude the oft-used, but terribly confusing, diagram of “parallel rays,” as a pinhole is capable of creating an image with no rays parallel. In essence, a pinhole enables the spreading out of an image over a larger surface so that each pixel can be separated, without letting any of the “mud” of confusing rays onto the landing area. Pinhole cameras *exploit the fact that images already exist at every point in space, and then enlarge them to a reasonable size*.

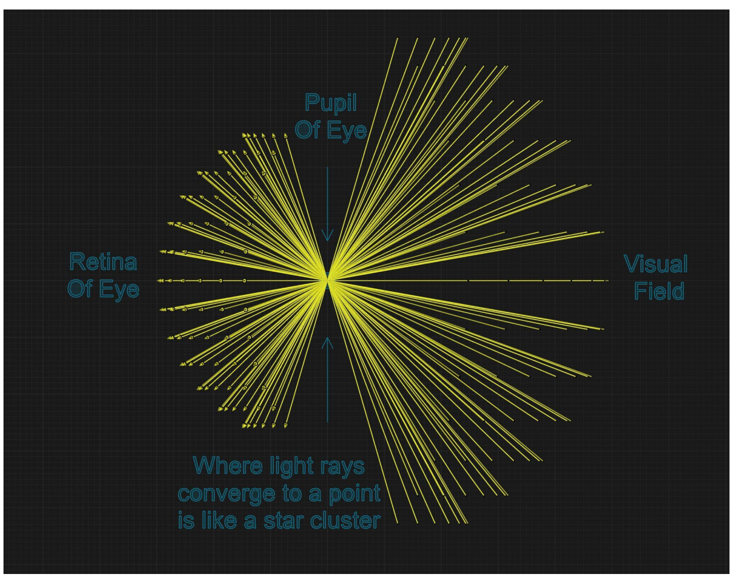


There exists a 360º (really, 41,253 square degree) picture at every tiny point in space; albeit to get a specific image, you have to take it from a specific place. *The pinhole camera doesn’t do anything magic — it just allows half of the image in any infinitesimal point to get magnified to a degree that is useful to us* (the other half of the sphere is occluded by the camera box!). The image is inverted because you’re catching the aftermath after all the rays have converged to a point and then kept going. But the 3D vector orientation of each ray is exactly the same while “right side up” and after getting inverted, much like clockwise actually is counterclockwise when viewed from the opposite side. If the eye and brain use the 3D vector rather than the pixels for creating perception, there is no need to “flip it back over.” Note that the inversion point of the rays, at the pinhole, is ground zero of where one is sampling the universe for an image. The back of the camera is useful, but its location is not relevant. The rays sketched here are two-dimensional, but you can imagine the rays from the third dimension. Note that everything from every degree of distance is “in focus” by definition.

The box design works out okay, as we are used to flat (planar) 2D images, but if we wanted every sensor on the back of the camera to already be at the right attitude to catch the rays of light (and represent the attitude of light captured), we would use a hemisphere camera:



The eyeball goes halfway, and uses an entire sphere, which means that the rod/cone sensors have to bend a little on the sides (like trees growing towards light) to be at the right attitude to catch the incoming light, which they do.`




The pinhole, despite its simplicity, has some drawbacks:

(1) Not much light is allowed in.
(2) Even with a fairly small opening (1 mm), it still allows light from a single point in the world to spread slightly by the time it reaches the back of the camera.
(3) With an extremely small opening (0.1 mm), the edges of the pinhole begin to diffract the light rays and cause some blurring.