

## **Answers to common questions in ray optics**

Assume an upright object being imaged from the left (entrance) to the right (exit).

### **1. The chief ray and the marginal ray: formal definition VS. convention**

Q. What defines a chief ray?

The chief ray is formally defined as the ray that starts from the edge of the object and passes through the axial point of the aperture stop. The ray passing through the axial point of the aperture stop naturally passes through the axial point of the entrance and exit pupils.

In case the field stop crops the image so that only the lower portion of the object is imaged, the chief ray should start at the highest position in the object plane that is not cropped in the image plane.

Q. What defines the marginal rays?

Marginal rays should pass through the edge of the aperture stop. The starting point of the marginal ray is not fixed by definition: rather, by convention, the ray starting from the axial point in the object plane is most often chosen to represent the marginal ray. The marginal rays show the angle of acceptance into the optical system.

### **2. Systems containing many apertures**

Q. How can I express an aperture using the ABCD matrix notation?

You don't need to, because an aperture cannot modify  $x$  or  $\theta$ . The location of the image is not modified by an aperture in the optical system. The size of the image is only changed if the aperture is a field stop that crops the image.

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### 3. Field stops

Q. Can an aperture stop also be the field stop at the same time?

The answer is no. While a small aperture stop will dim the image to become darker, it will never “crop” the image. Let’s consider the simplest case of a single-element optical system in Figure 1.

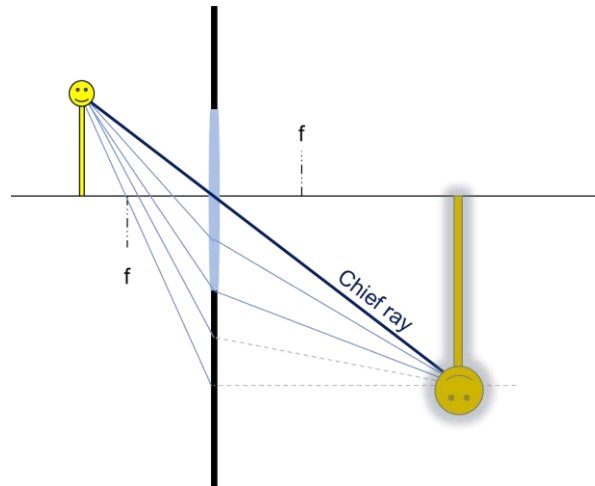


Figure 1. A single lens system

Given an optical system and an object, you can always determine the aperture stop based on the location of the object. In Figure 1, the aperture stop is the lens itself. The chief ray is defined to pass through the axial point of the aperture stop, regardless of the size of the object. In other words, however small your aperture stop may be, it will never “cut away the view” of the object. In contrast, a field stop is like a small window that blocks the sight of the top of a tall tree. For a given object plane, the field stop determines the highest point in the object plane that can be imaged.

Therefore there is no field stop in the system of Figure 1. When you have 2 limiting apertures (including the lenses) inside the optical system, the one that is not the aperture stop immediately becomes the field stop. Also note that the size of the field stop does not affect the image other than possibly cropping the size: whether the FS is “just large enough” or “much larger than needed” doesn’t matter. The size of the aperture stop, on the other hand, gradually changes the brightness of the image.

**SUMMARY: An aperture stop dims the image while a field stop crops the image. They cannot be the same aperture.**

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