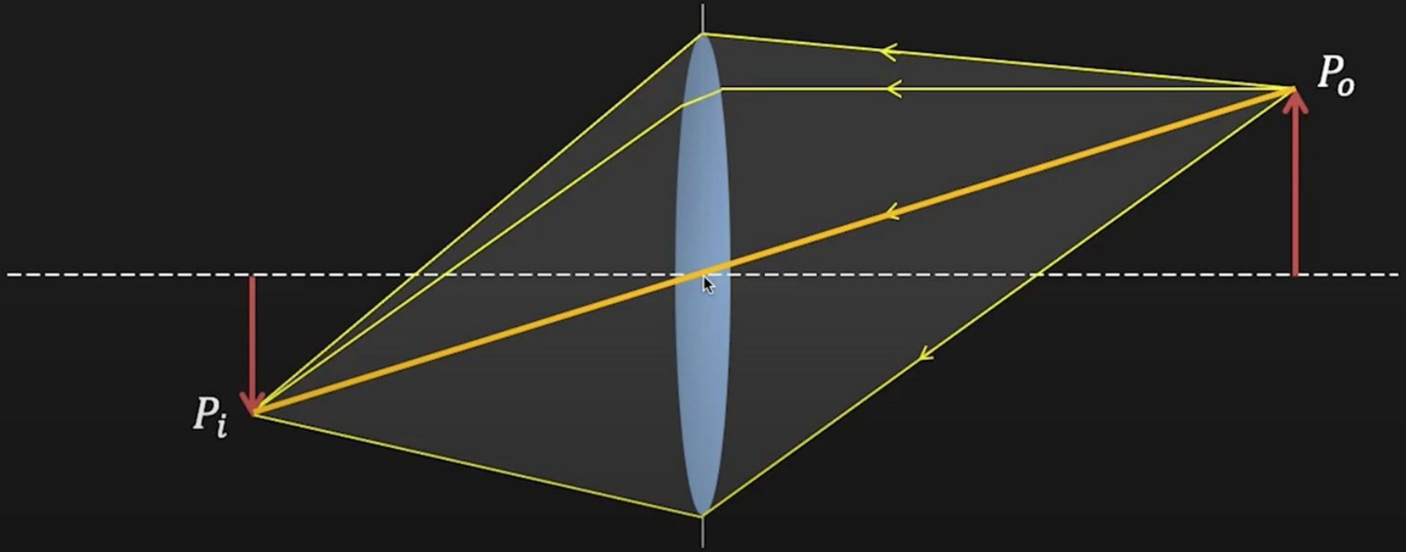
Image Formation

Lenses

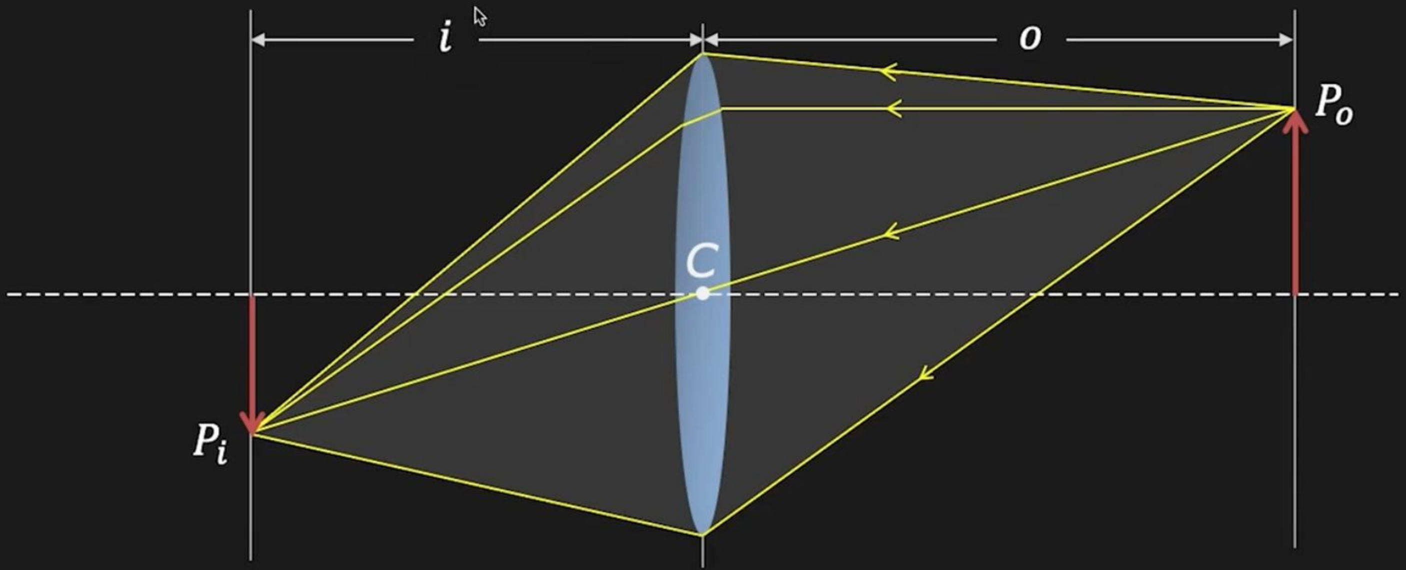
Lenses

Same projection as pinhole, but gather more light!



Focal length (f) determines the lens' bending power

Gaussian Lens (Thin Lens) Law



f: focal length

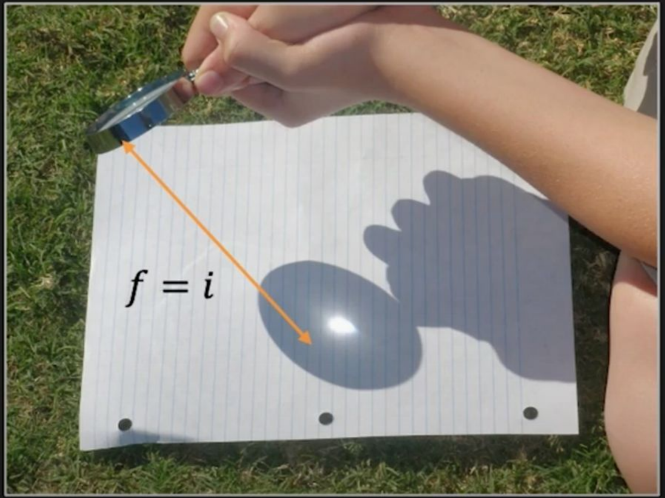
i: image distance

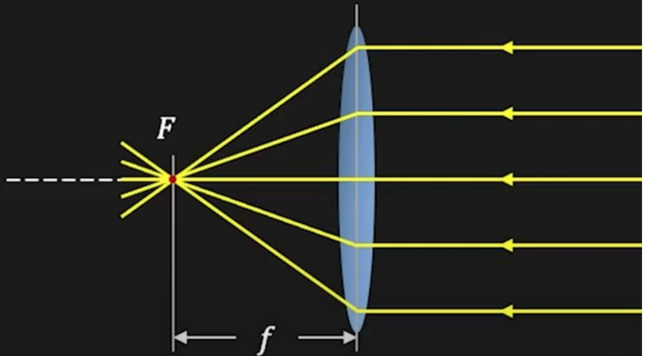
o: object distance

$$\boxed{\frac{1}{i} + \frac{1}{o} = \frac{1}{f}}$$

How to Find the Focal Length?

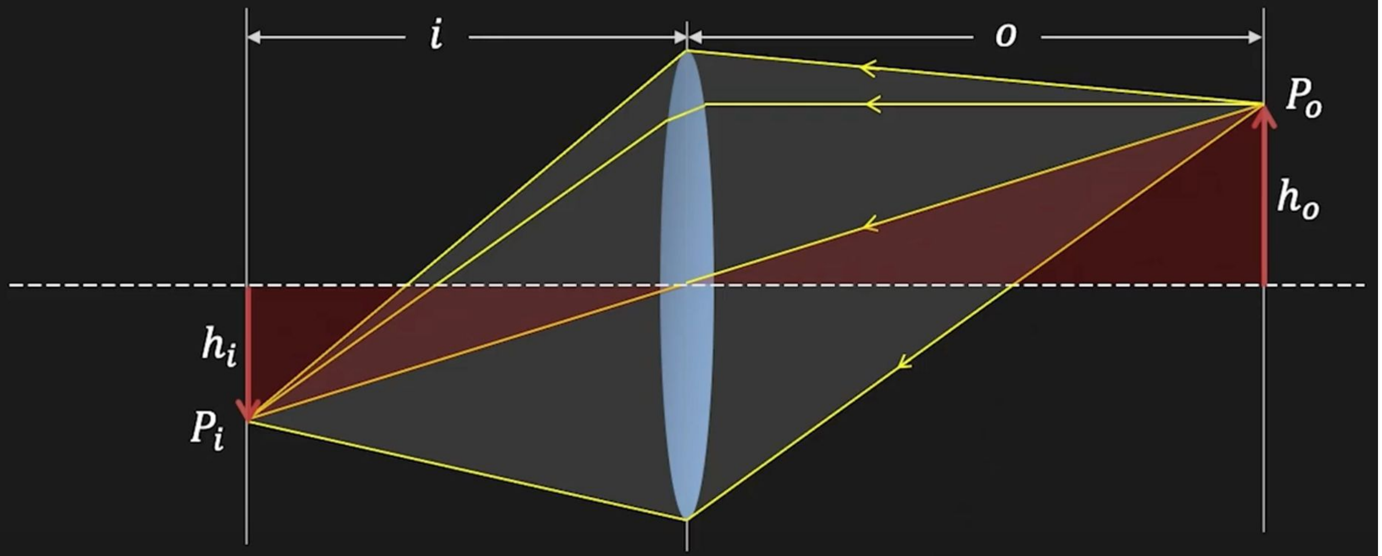
$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f} \quad \Rightarrow \quad \text{If } o = \infty\text{, then } f = i$$





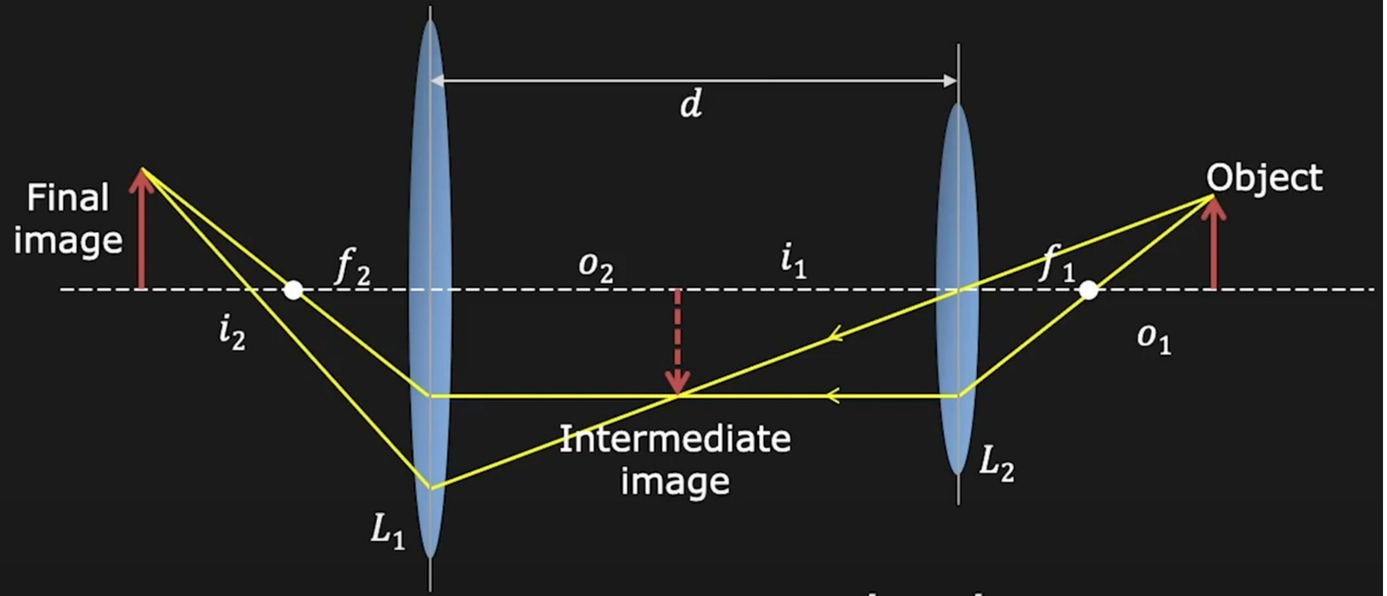
Focal length: Distance at which incoming rays that are parallel to the optical axis converge.

Image Magnification



Magnification: $\boxed{m = \dfrac{h_i}{h_o} = \dfrac{i}{o}}$

Two Lens System

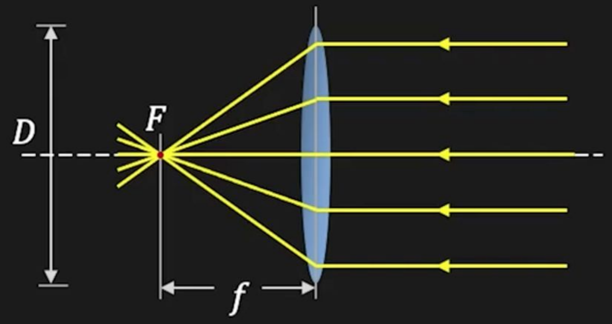


Magnification: $m = \dfrac{i_2}{o_2} \cdot \dfrac{i_1}{o_1}$

Zooming: Move lenses to change magnification

Aperture of Lens

Light receiving area of lens, indicated by lens diameter.



Aperture can be reduced/increased to control image brightness

f-number (f-stop, f-ratio) of Lens

Convenient to represent aperture as a fraction of focal length

$\boxed{\text{Aperture: } D = {}^{f}/_{N}}$ $\boxed{\text{f-Number: } N = {}^{f}/_{D}}$

where N is called the f-Number of lens.

Ex: A $50mm$ focal length, f/1.8 lens implies:

$N = 1.8$ $(D = 27.8mm)$ when aperture is fully open

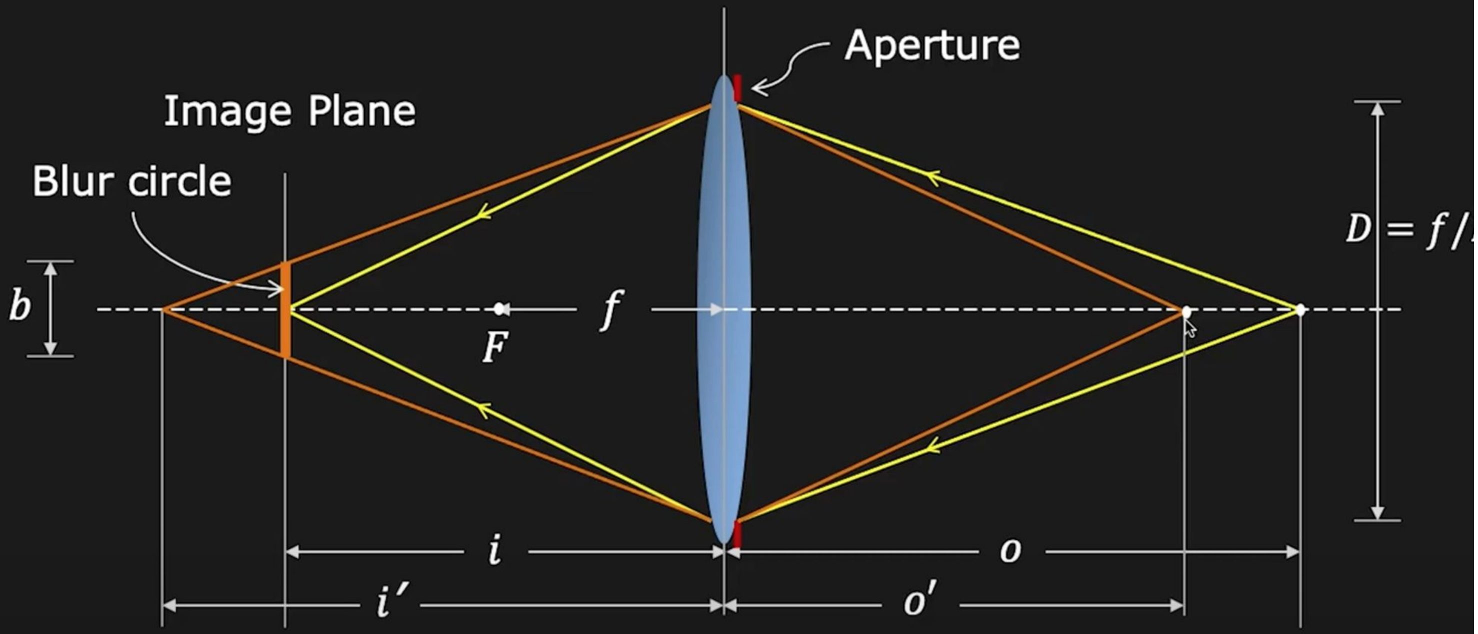
$N = 1.8$

$N = 4$

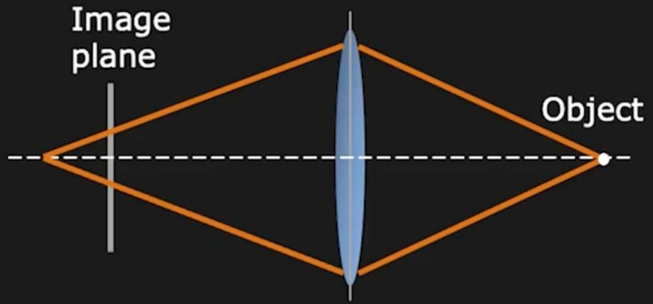
$N = 8$

$N = 11$

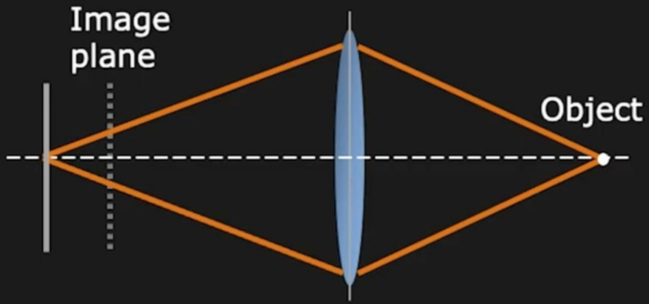
Lens Defocus



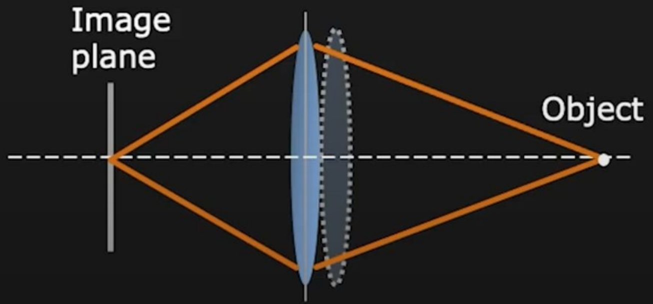
Focusing



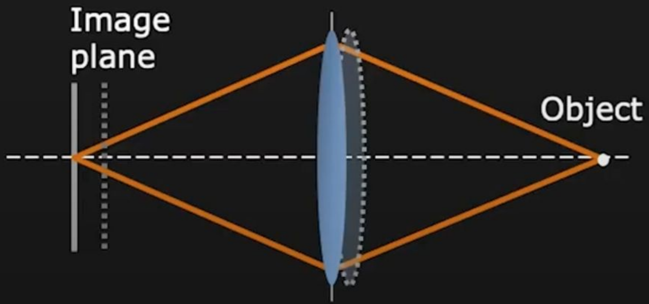
Defocused System



Move the image plane

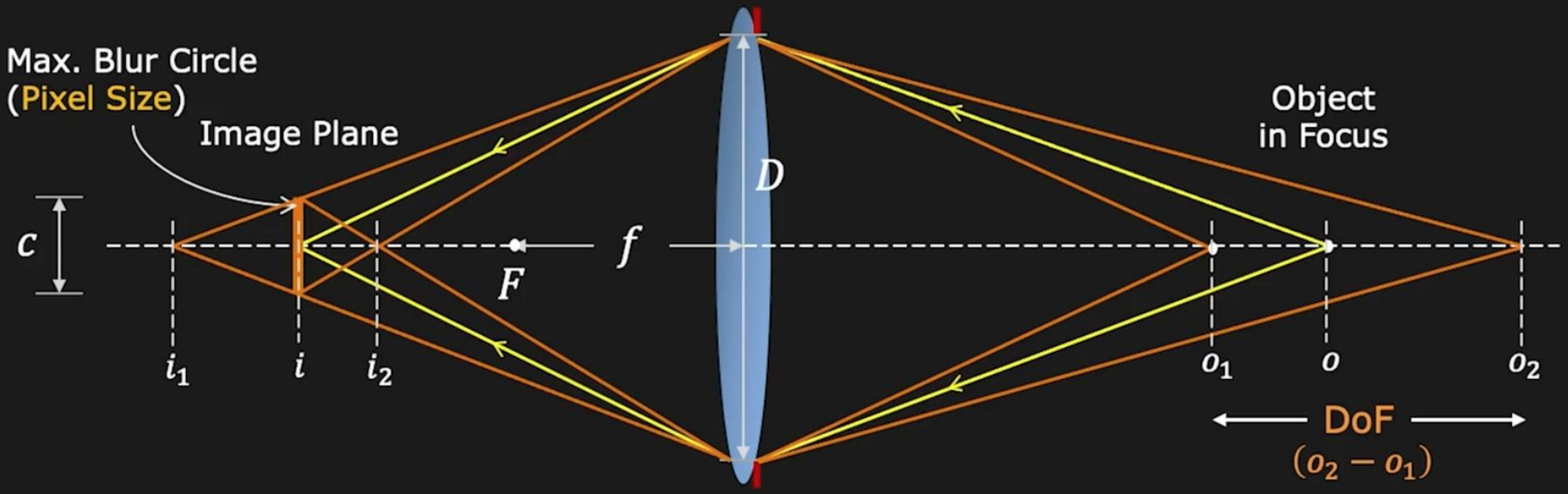


Move the lens



Move both lens and image plane

Depth of Field (DoF)



References

1. Columbia University https://fpcv.cs.columbia.edu