Camera and Photography

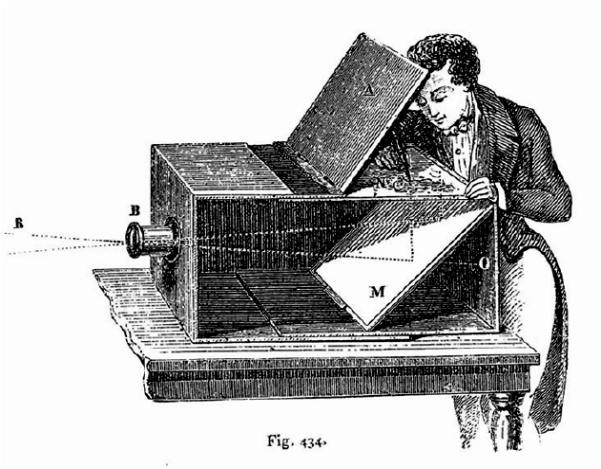
Essential parts of lens based cameras:

- Different types of lenses
  - focus
- Aperture
  - Depth of field/focus
- Shutter speed

wide-angle

standard

telephoto



Lens Based Camera Obscura, 1568

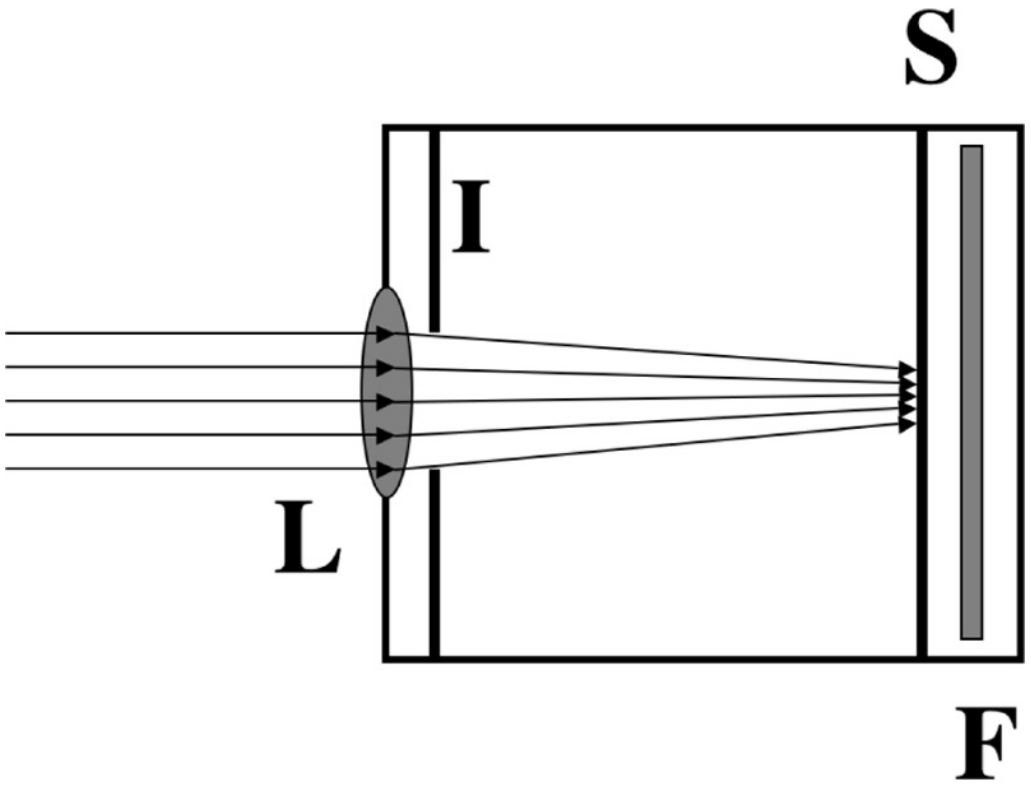
Camera - Parts

Lens

Iris Aperture – Adjust intensity

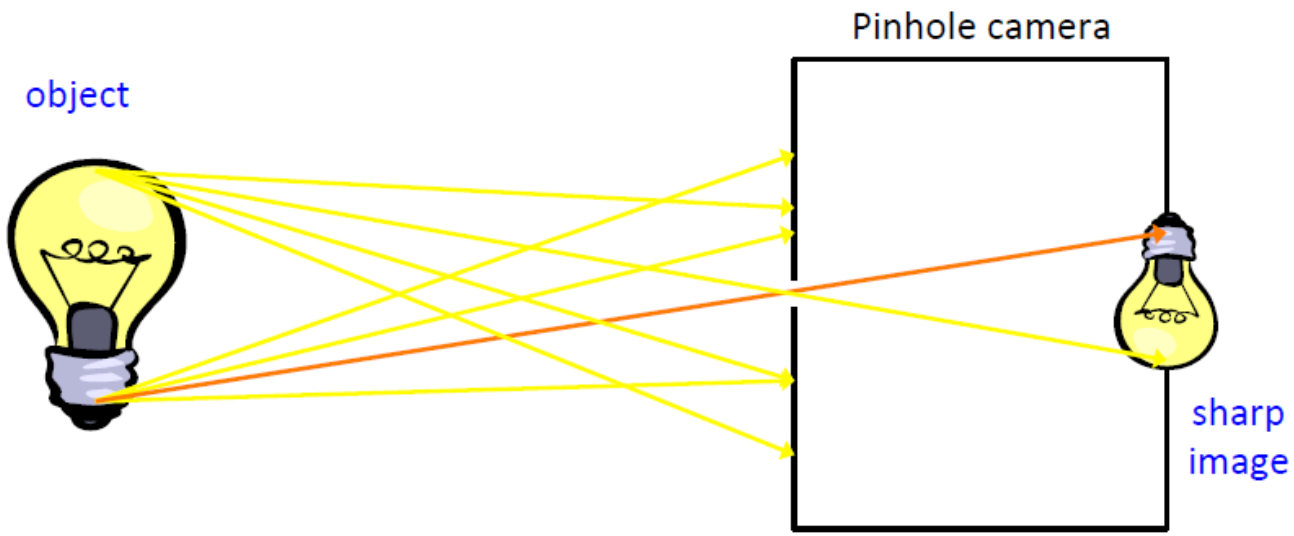
Shutter – Quick open/Close

Film or Detector



Pinhole Camera

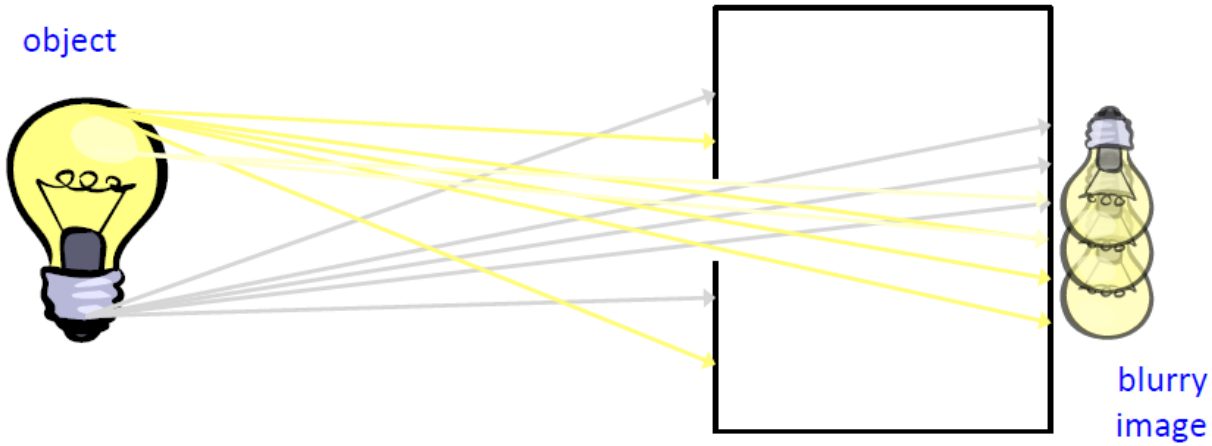
Simplest lens-less camera



Light rays from each point on the object reach one point (and no other point) on the screen, and no rays from other points on the object reach that same point on the screen.

This produces a *focused image* at every plane, independent of the position of the object (though very faint)

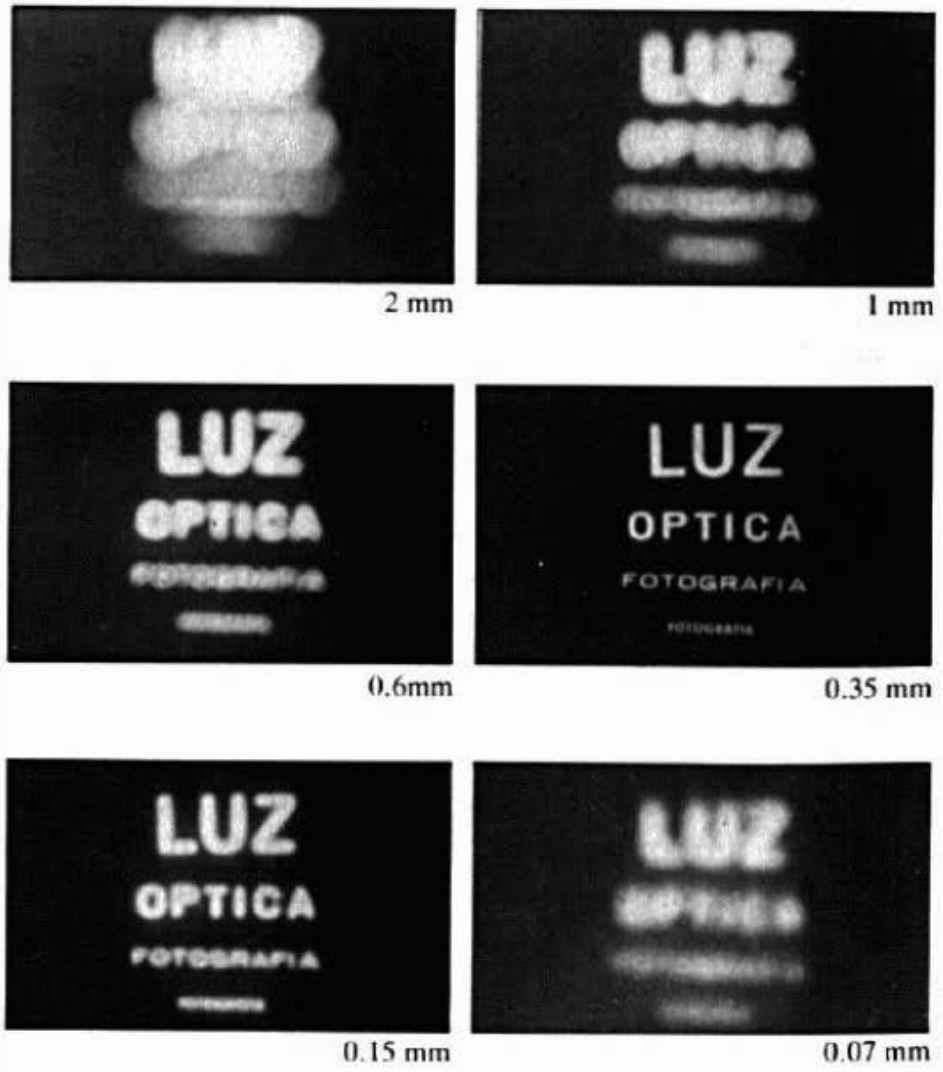
Poor image quality with pinhole camera



Increasing the size of the hole in a pinhole camera, allows more light to enter. But the image gets blurry, because rays from each point on the object hit more than one spot on the screen, and rays from more than one point on the object reach the same spot on the screen.

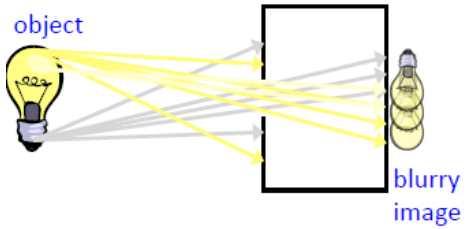
Opening too large => blurry image

Shrinking the opening (aperture)



- Pinhole too big - many directions are averaged, blurring the image
- Pinhole too small - diffraction effects blur the image
- Generally, pinhole cameras are *dark*, because a very small set of rays from a particular point hits the screen.

Add lens to poor pinhole camera



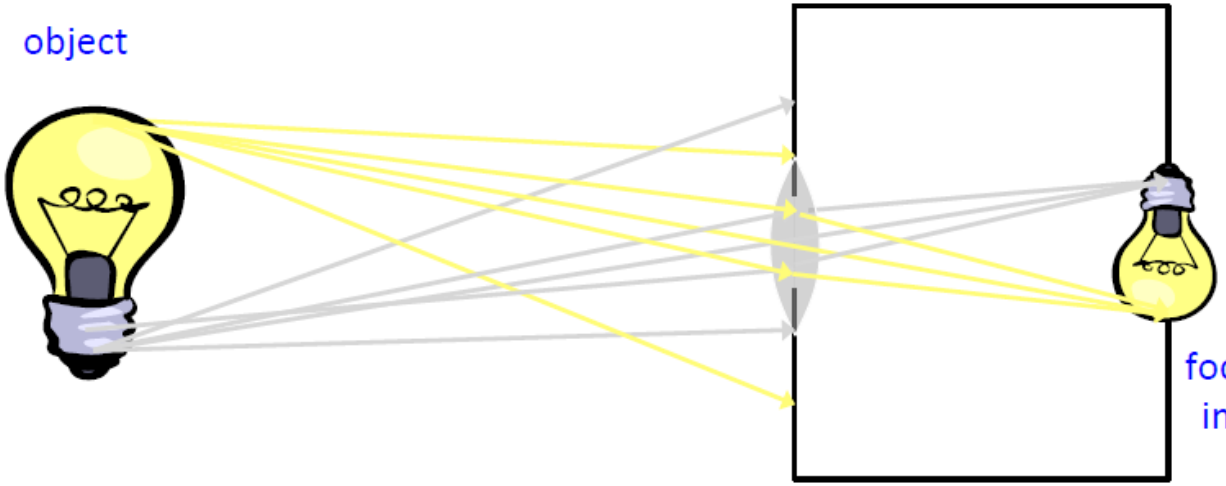


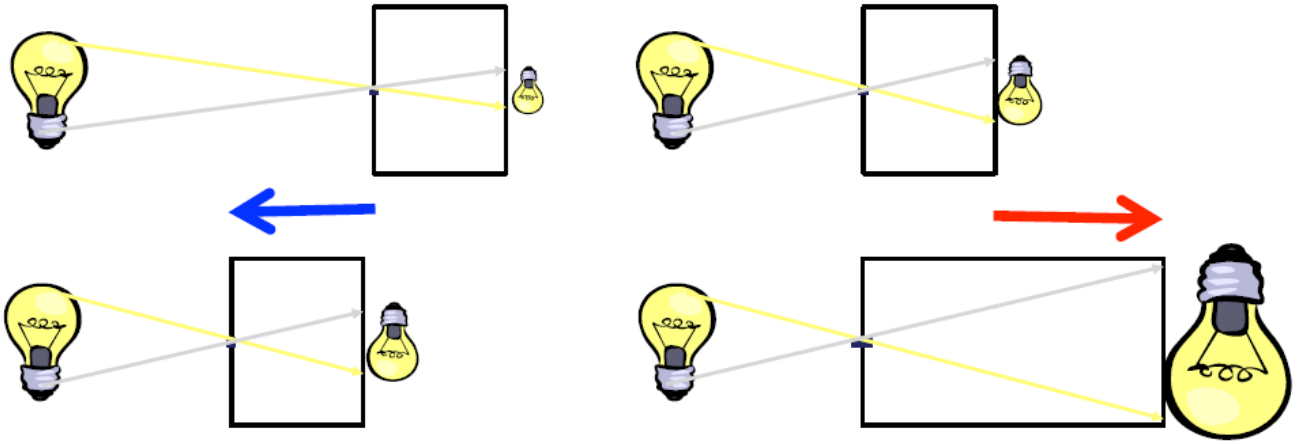
Image inverted

Adding a lens bends the rays so that rays from each point on the object reach only one point on the screen, and no rays from other points on the object reach that same point.

This produces a *focused image* on the screen.

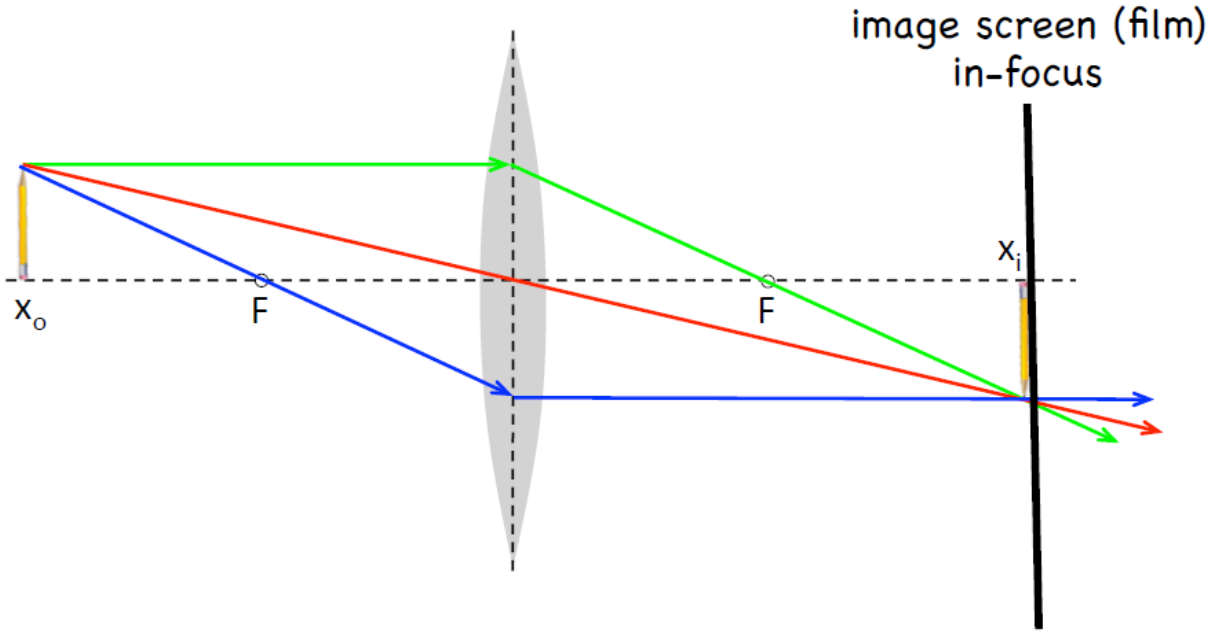
Camera zoom and image size

Pinhole camera *(for simplicity):*



- To produce a larger image with a pinhole camera, either decrease the distance from the object to the camera, or increase the distance from the pinhole to the back screen of the camera.
- The image stays in focus because only one ray from each point on the object gets through the pinhole and reaches the screen.

Reminder: Image formation of converging lens



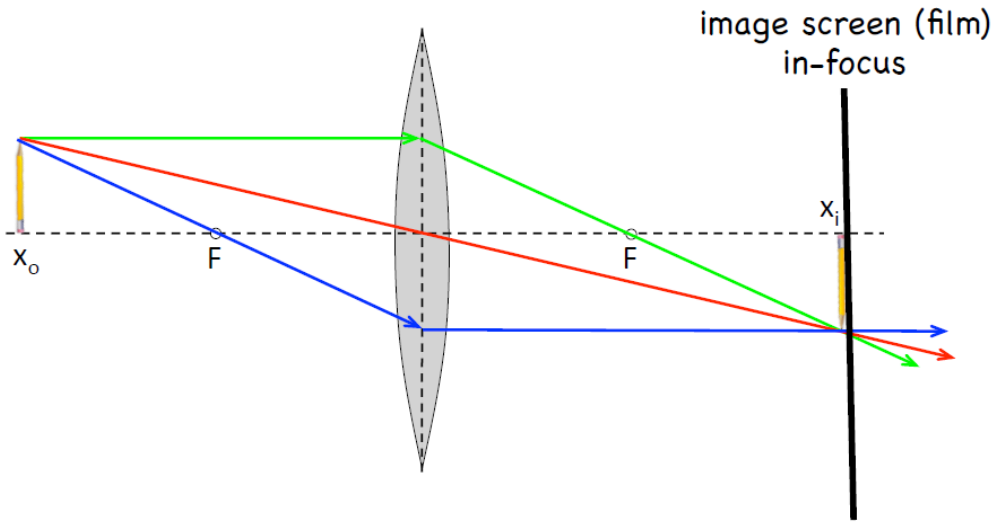
$x_o = 2f$ (camera image on film):

The image is *real*, *inverted* and of the *same size* as the object. More generally this will depend on the position of the object x_o relative to the focal point F of the lens.

If object moves (for fixed f) so will the image -> must refocus

Thin lens equation: $$\frac{1}{x_o} + \frac{1}{x_i} = \frac{1}{f}$$

Object distance and image location



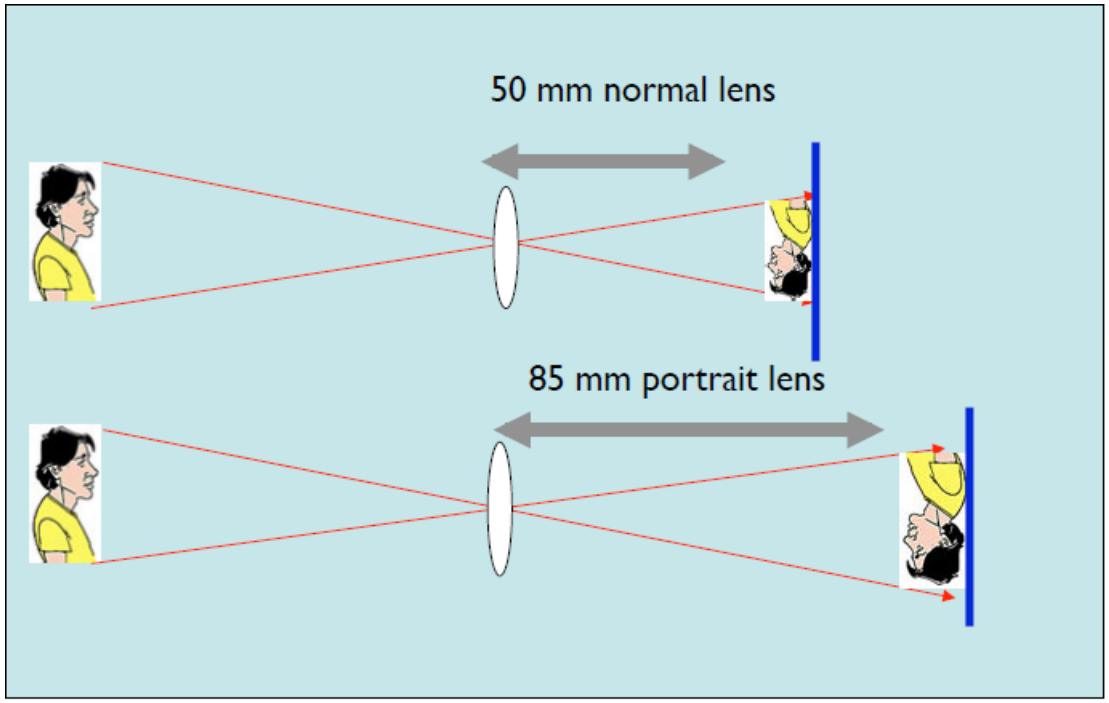
What happens to the image if the object distance, x_o increases?

$$\frac{1}{x_o} + \frac{1}{x_i} = \frac{1}{f}$$

Image moves closer to the lens

-> so must refocus

Focal length of camera lens

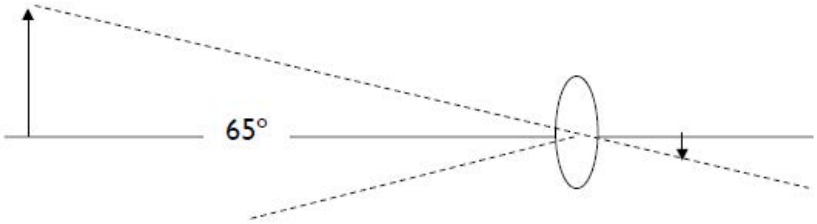


$$\frac{1}{x_o} + \frac{1}{x_i} = \frac{1}{f}$$

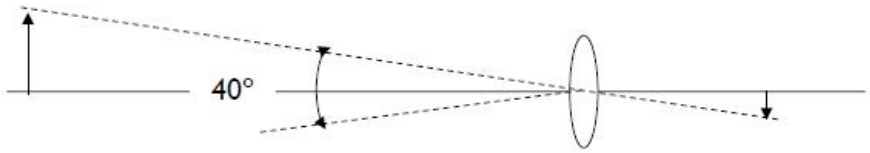
Lens with the longer focal length produces image at larger x_i
→ Magnification is larger for larger f

Common focal lengths in cameras

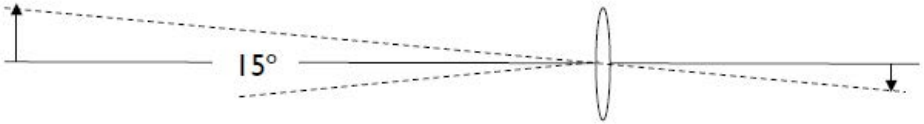
28 mm f. l.
wide angle



50 mm f. l.
normal



135 mm f. l.
telephoto



Lens comparison

wide angle

15 mm lens

standard

35mm lens

standard

50mm lens

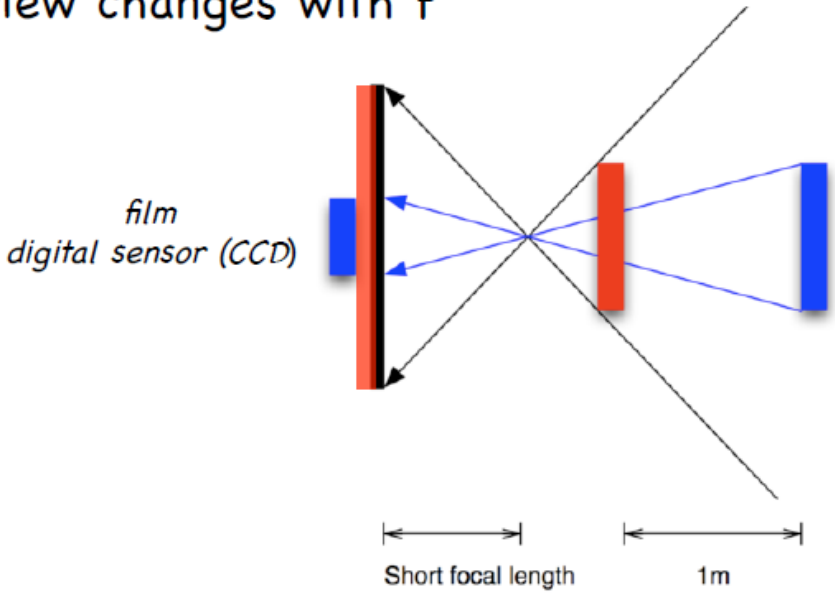
telephoto

135mm lens

Wide-angle lens

Wide-angle ("fish-eye") lens
- short focal length
- smaller image
- larger field of view
- opposite function of zoom lens

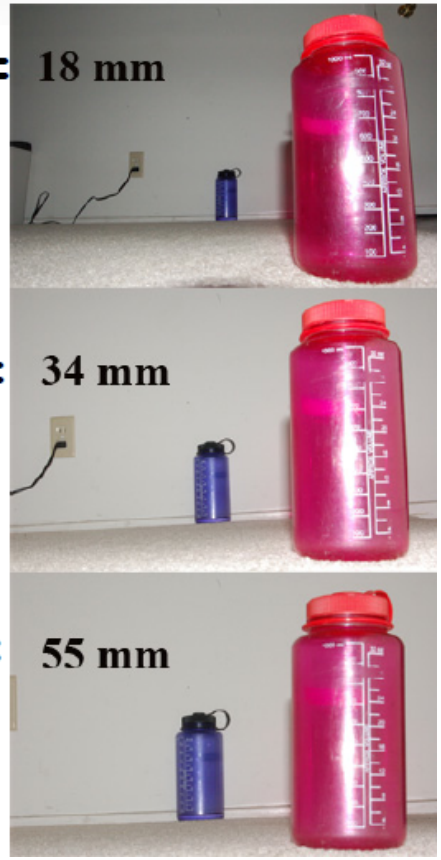
Images at three focal length:
- keeping the camera's distance (size) from the pink bottle fixed (fills the frame)
- blue bottle size changes
- field of view changes with f



f= 18 mm

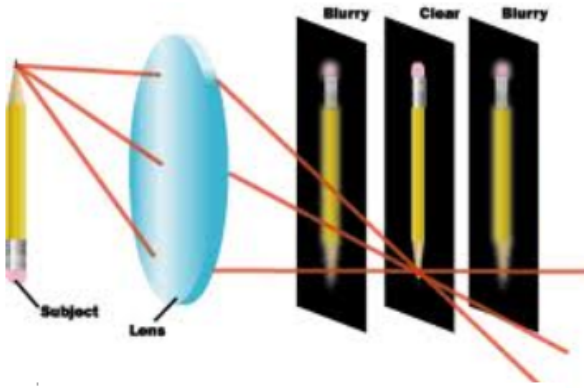
: 34 mm

: 55 mm

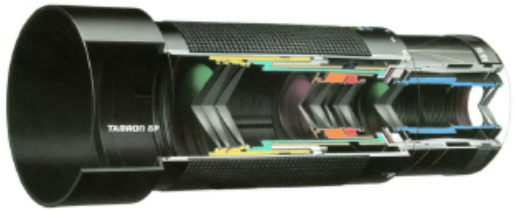


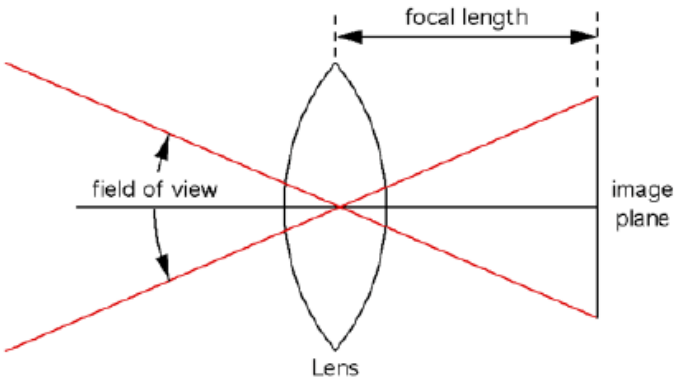
Photography principles

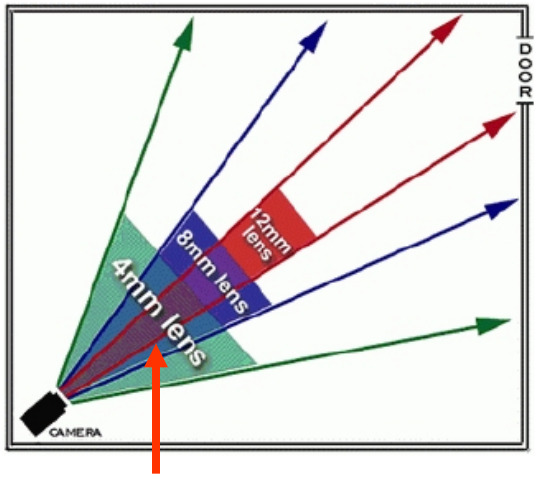
1. Camera focuses by moving the lens closer/further from the film



2. Longer focal length -> larger image magnification





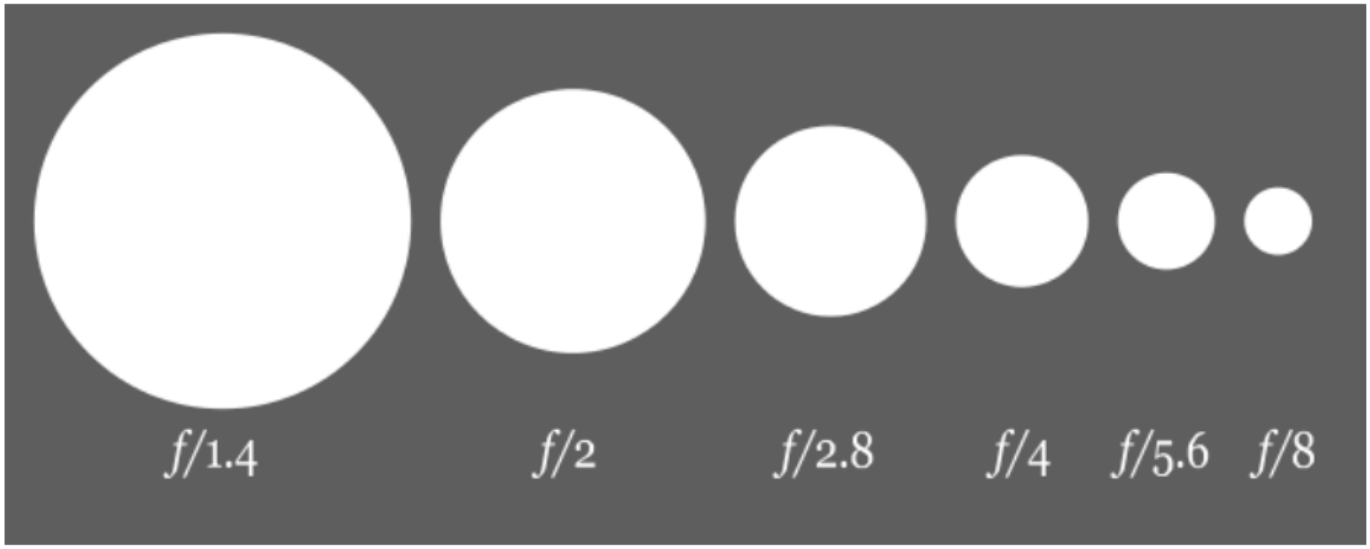


More likely 50 mm lens

F-Number

F-number = focal length/diameter of lens = f/D

(focal ratio, f-ratio, f-stop, inverse of NA)



f-number = 1.4 2 2.8 4 5.6 8

multiply f-number by √2 -> divide D by √2 -> 1/2 reduction in light

"fast" lens — "stopping down" the lens — "slow" lens

f-number notation: f/# ⟷ f-# ⟷ f#

e.g., f-2 pronounced "eff two" (strictly speaking f/# gives aperture diameter)

small f-number -> bright image -> can afford fast shutter speed

ex: (f = 200mm)/(25mm diameter) = f-number 8 -> f/8

F-Number

F-number = focal length/diameter of lens = f/D
(focal ratio, f-ratio, f-stop, inverse of NA)

Big diameter lens = low f-number, e.g., f-number 1.4

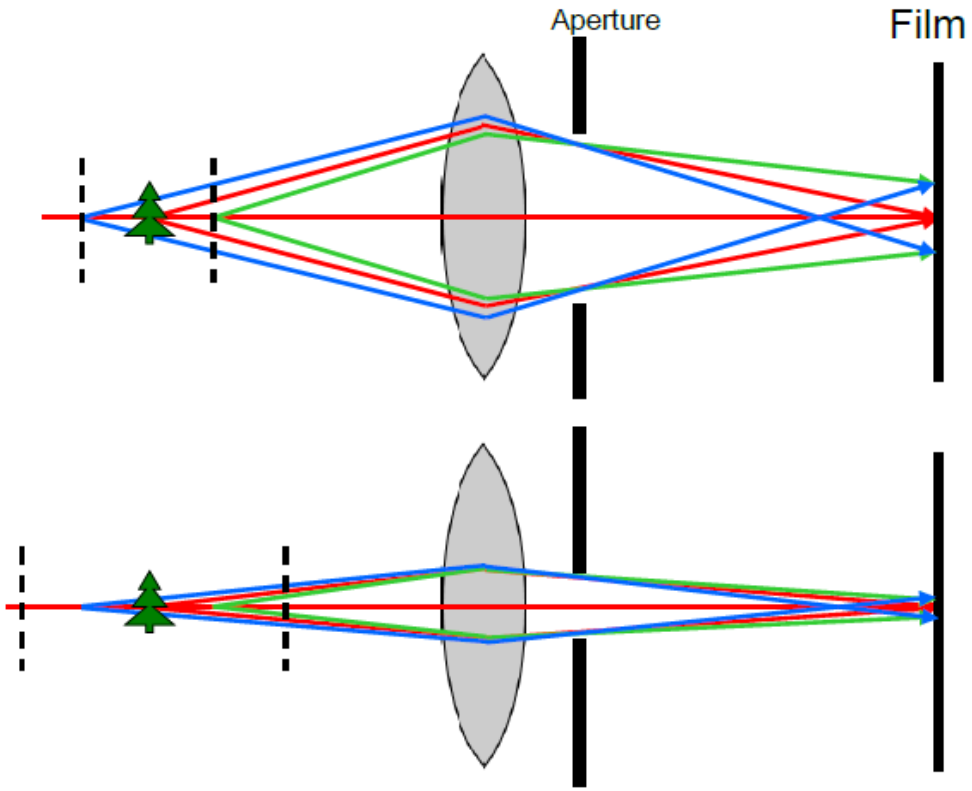
Heavy, cost more, works in low light and indoors

Small diameter lens = big f-number, e.g., f-number 3.5

Weigh less, less expensive, used for outdoors

small f-number -> bright image -> can afford fast shutter speed
ex: (f = 200mm)/(25mm diameter) = f-number 8 -> f/8

Depth of Field



f / 5.6

f / 32

- Changing the aperture size affects depth of field
  - A smaller aperture increases the range in which the object is approximately in focus

Vary Aperture

Large aperture = small DOF

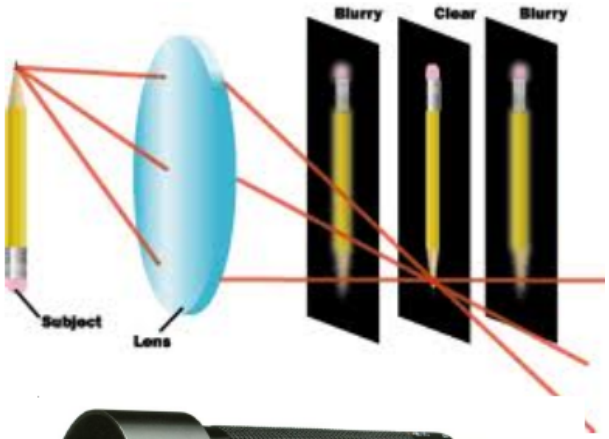
Small aperture = large DOF

Adjust f-number

depth of field comparison

Photography principles

1. Camera focuses by moving the lens closer/further from the film



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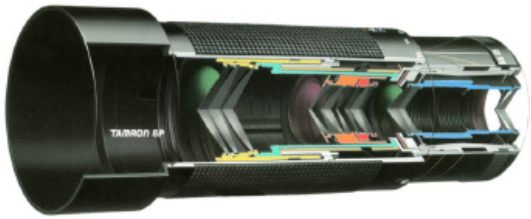
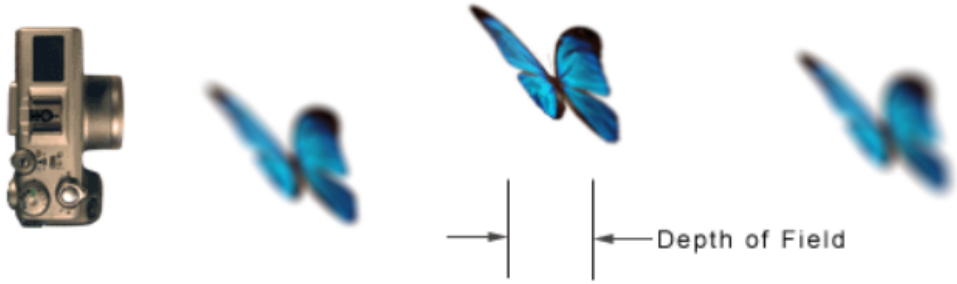


3. Bigger lens, aperture (small f-number)

   -> narrower depth of field, DOF

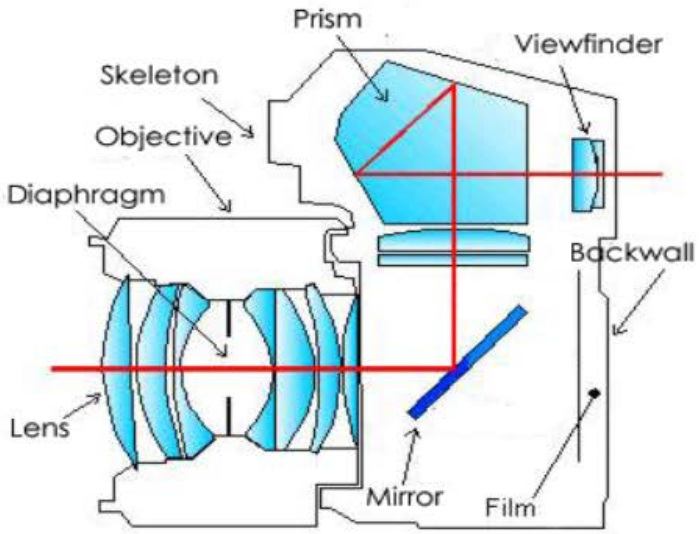


Two common camera types

Point & shoot
one lens, viewfinder,
liquid crystal display (LCD)

LCD is on the back

Single lens reflex (SLR)
interchangeable lenses



Shutter speed

Shutter – opens the camera lens for a controlled amount of time, to let light in, exposing the film or CCD detector

The longer the shutter open (1 second vs 1/2 second) the more light energy hits the film -> *shutter speed -> exposure time*

Common shutter speeds

1/15 sec
1/30 sec
1/60 sec
1/125 sec
1/250 sec
1/500 sec

each change lets in half the light

factor of 1/2 in light energy entering the camera

Photography principles

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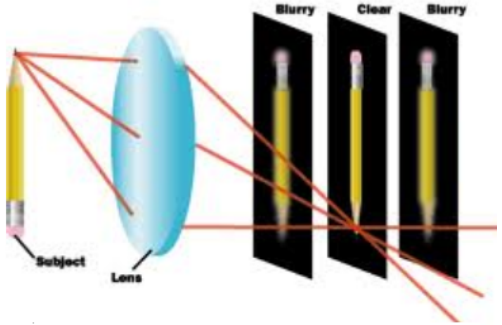

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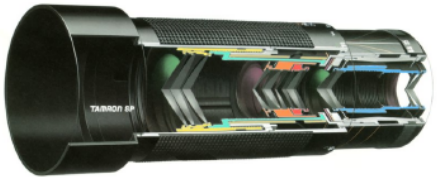
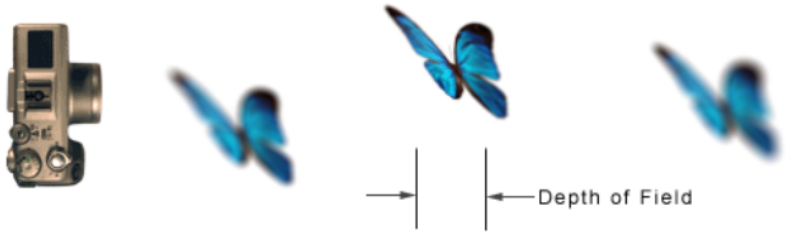


3. Bigger lens, aperture (small f-number)

   -> narrower depth of field, DOF



4. Faster shutter speed →less light power

Long exposure time

CE: Tavira – Rio Gilao

Exposure ~ 60 s

street at night
exposure time 30 seconds

Photography principles

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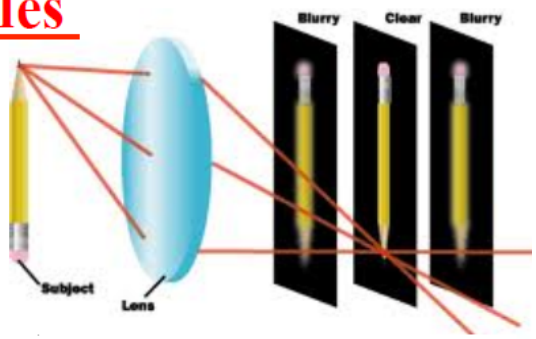

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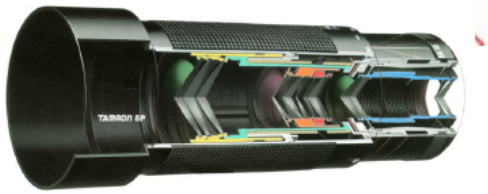
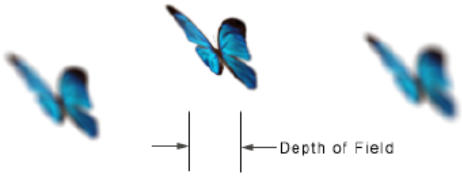


3. Bigger lens (small f-number) -> narrower depth of field, DOF

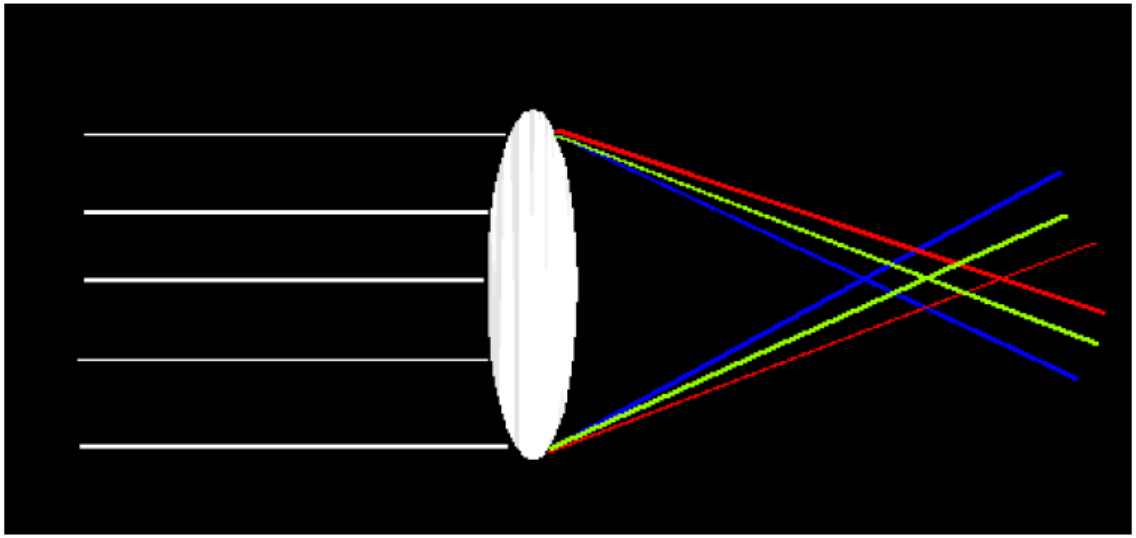


4. Faster shutter speed -> less light power
5. Small f-number -> bright image

change with lens and aperture

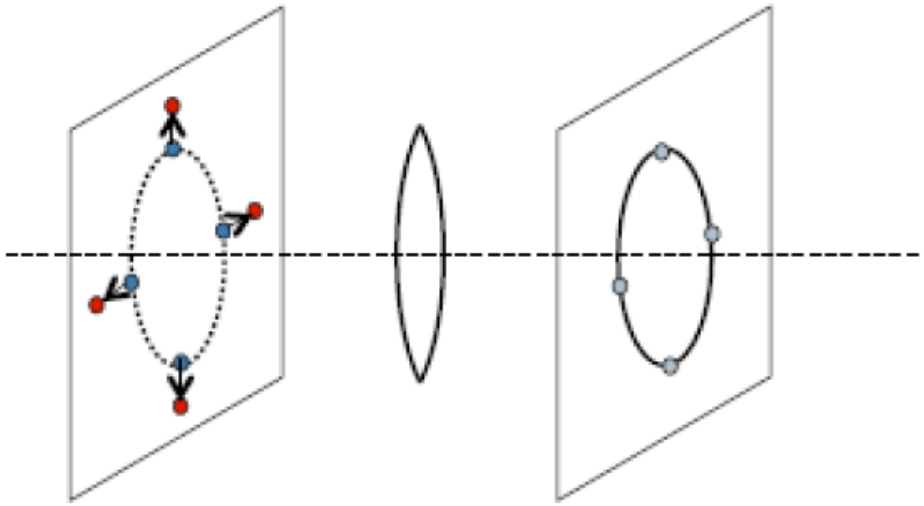
Lens Flaws: Cromatic Aberration

- Lens has different refractive indices for different wavelengths.
- Could cause color fringing:
  - i.e., lens cannot focus all the colors at the same point.



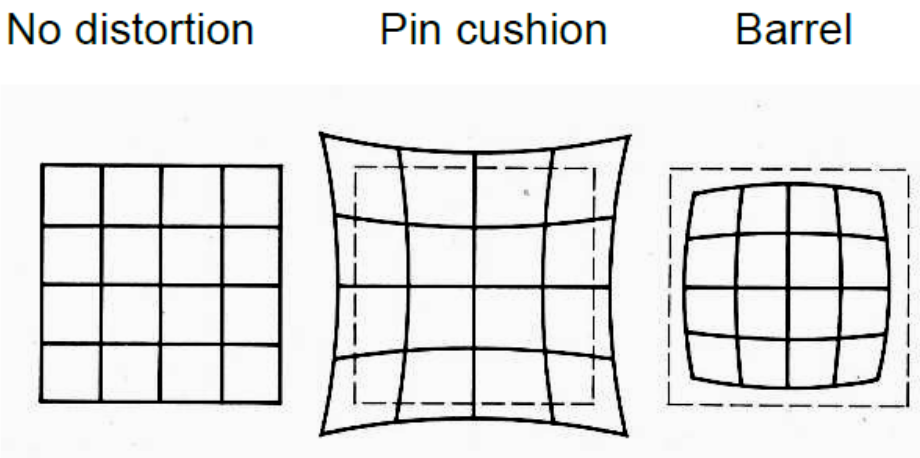
Lens Flaws: Cromatic Aberration

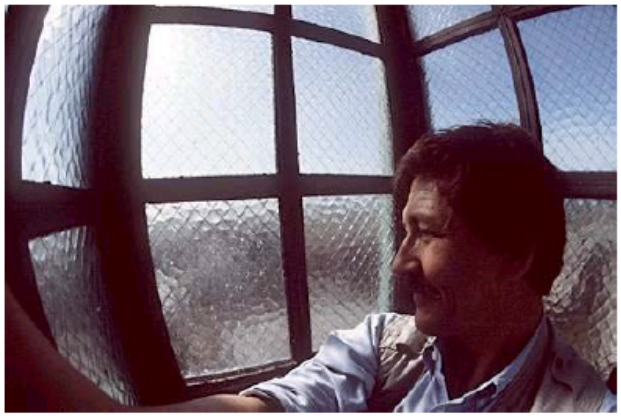
Lens Flaws: Radial Distortion



- Straight lines become distorted as we move further away from the center of the image.
- Deviations are most noticeable for rays that pass through the edge of the lens.

Lens Flaws: Radial Distortion





Photography

Photograph = science + art