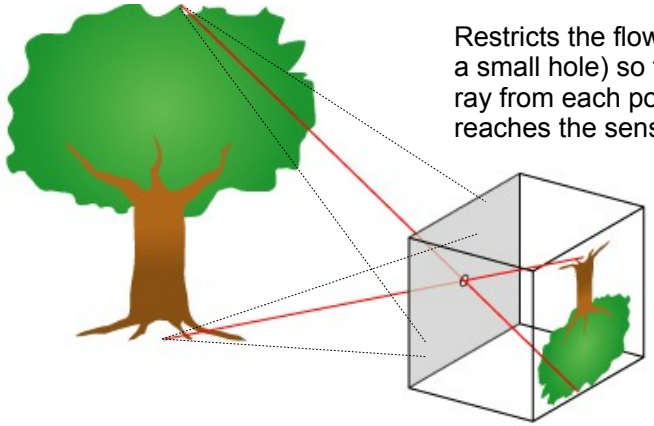
Content

- **Physics of image formation**
  - light
  - reflectance
  - optics

Pinhole camera



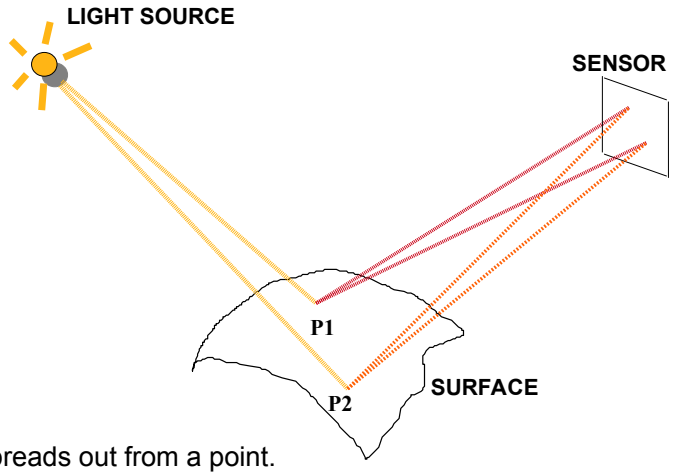
Restricts the flow of light (using a small hole) so that only one ray from each point in the world reaches the sensor.

Note: image inverted

"Focus" means that all rays coming from a scene point converge into a single image point.

"Exposure" is the time needed to allow enough light through to form an image (the smaller the aperture, the longer the exposure time). The longer the exposure the more blurred an image is likely to be.

Focusing Light

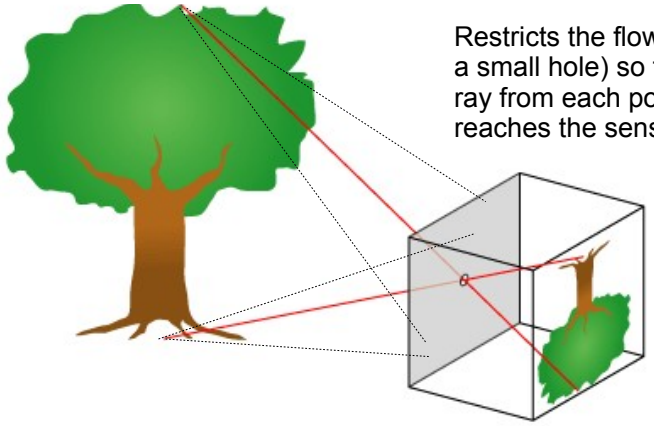


Light spreads out from a point.

Without some kind of optics each location on the sensor will register light coming from many different points in the world.

No image will be formed.

Pinhole camera



Restricts the flow of light (using a small hole) so that only one ray from each point in the world reaches the sensor.

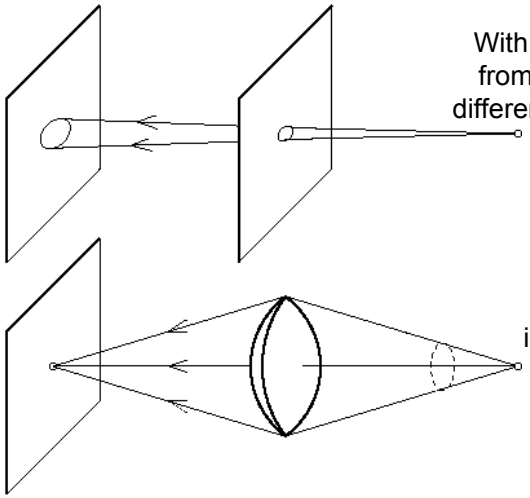
Note: image inverted

Small pinhole: sharp focus but dim image (long exposure time)

Large pinhole: brighter image (shorter exposure) but blurred

To produce an image that is both bright and in focus requires a lens

Lensed camera



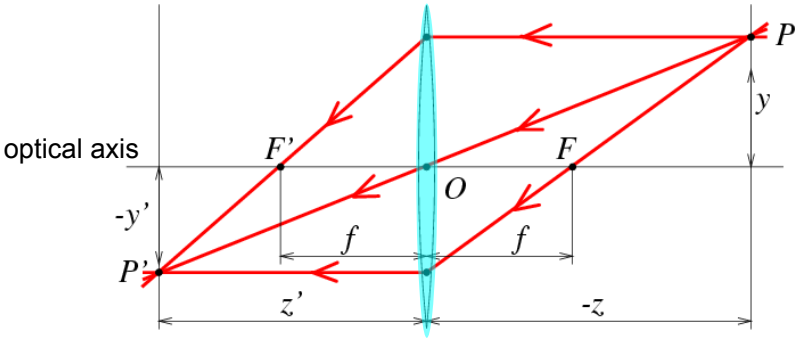
With a large pinhole, light rays from the same point project to different locations on the image. The image is blurred.

By focusing rays from the same point onto a single image location, a lens can keep the image sharp while gathering more light.

Cost: image focused for only a restricted range of object positions

Thin lenses

A Lens works by refracting light.

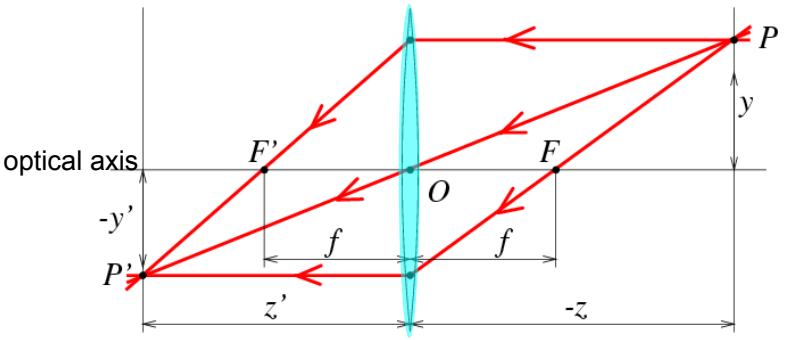


F' = focal point, f = focal length, O=optical centre

- Rays passing through O are not refracted
- Rays parallel to the optical axis are refracted to pass through F'.
- Rays passing through point F are refracted to be parallel to the optic axis.

f depends on the curvature of the lens and the material it is made from.

Thin lenses

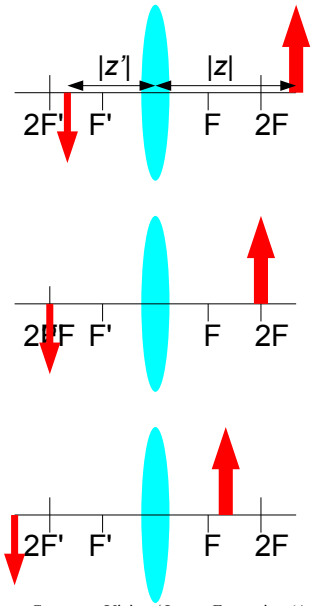


An object located at distance z from the lens has an image formed at depth at z' from the lens according to the "thin lens equation":

$$\frac{1}{f}=\frac{1}{|z|}+\frac{1}{|z'|}$$

Hence, depth of the image depends on the depth of the object as well as the focal length of the lens.

Depth of focus



$$\frac{1}{f}=\frac{1}{|z|}+\frac{1}{|z'|}$$

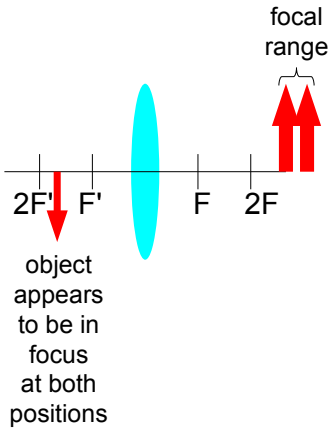
For a lens with a fixed focal length, the depth of the image plane required to bring an object into focus varies inversely with the depth of the object.

At the extremes: if the object is at infinity the image is formed at F', if the object is at F (or closer) no image can be formed.

For a short focal length camera, almost all objects will be located more than 2 focal lengths from the lens (top figure)

Placing the receptor plane at a fixed depth in the range $z' \in [F', 2F']$ will provide an acceptable image for objects in a wide range of depths greater than 2F.

Focal range



Focal range is defined by the range of object locations such that blurring due to the difference between the receptor plane and the focal plane is less than the resolution of the receptor device.

Decreasing the aperture size increases the focal range, but it decreases the amount of light available to the receptor.

As the aperture decreases to a pinhole we recover the infinite focal range of the pinhole camera!