Lecture tutorial 2F

Microscopes

Introduction

- microscopes are optical instruments used to magnify small, close objects that are not visible to the naked eye
- they enable the observation of fine structural details in biological, material, and other samples

Components

- objective lens is placed close to the specimen and creates a magnified real image
- eyepiece lens (ocular) further magnifies the image formed by the objective
- light source and stage are used to illuminate and support the specimen

Total magnification

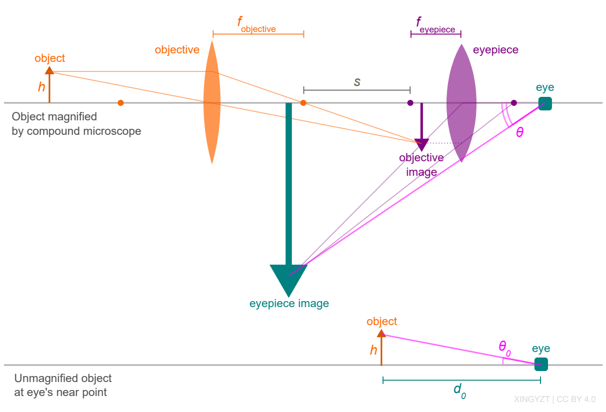
- the total magnification M is the product of the magnifications of the objective and the eyepiece
- for an objective with focal length f_o and an eyepiece with focal length f_e, the approximate total magnification is

$$M = \frac{L}{f_o} \cdot \frac{25, \mathrm{cm}}{f_e}$$

- here, L is the tube length and 25 cm is the near point distance for relaxed viewing

Image formation

- the objective lens forms a real, inverted, and magnified intermediate image of the object
- the eyepiece lens acts as a magnifier, producing a virtual, enlarged image of the intermediate image
- the final image is virtual, inverted, and appears at a comfortable viewing distance



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Advantages and limitations

- advantages include high magnification and resolution for small-scale structures
- limitations include the need for precise focusing, illumination, and often sample preparation
- resolution is limited by diffraction, with a theoretical limit of about $0.61\lambda/\mathrm{NA}$ where NA is the numerical aperture

Telescopes

Introduction

- telescopes are optical instruments designed to magnify distant objects
- they allow observation of celestial bodies and faraway phenomena in greater detail

Components

- objective lens/mirror collects light from the object and forms a real image
- eyepiece lens magnifies the image formed by the objective

Angular magnification

- the total angular magnification M of a telescope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object as seen by the unaided eye
- for an objective with focal length f_o and an eyepiece with focal length f_e, the magnification is given by

$$M = \frac{\theta'}{\theta} = \frac{h/f_e}{h/f_o} = \frac{f_o}{f_e}$$

- with the small angle approximation $\theta' \approx h/f_e$ and $\theta \approx h/f_o$

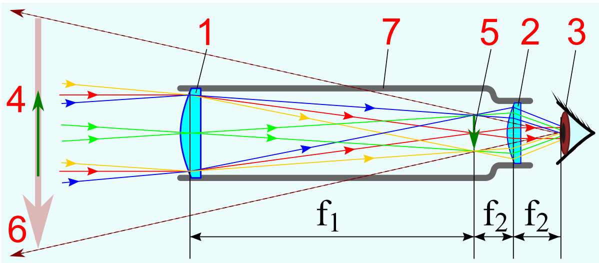
Image formation

- the image of the first lens (objective) becomes the object for the second lens (eyepiece)
- objective lens forms a real, inverted image near its focal point
- eyepiece lens acts as a magnifying glass producing a virtual, inverted final image

Types of telescopes

Refracting telescopes (Keplerian)

- design uses two converging lenses
- objective lens has a long focal length to collect light and form a real, inverted, diminished image at its focal plane
- eyepiece lens has a short focal length and magnifies the real image
- advantages include simple design and good image quality for small apertures
- disadvantages include heavy, expensive objective lenses and chromatic aberration



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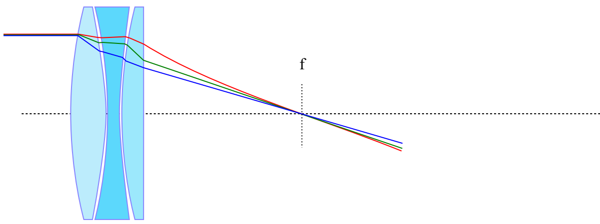

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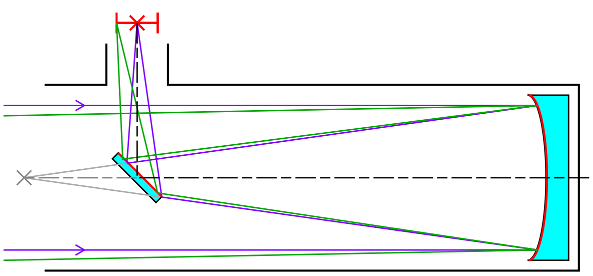
Reflecting telescopes (Newtonian)

- design uses a concave mirror as the objective to collect and focus light
- light reflects off the primary mirror forming a real, inverted image at the focal point
- a secondary flat mirror reflects the image to the side for viewing through an eyepiece
- advantages include absence of chromatic aberration and easier manufacture of large mirrors
- disadvantages include diffraction effects from the secondary mirror and the need for periodic realignment



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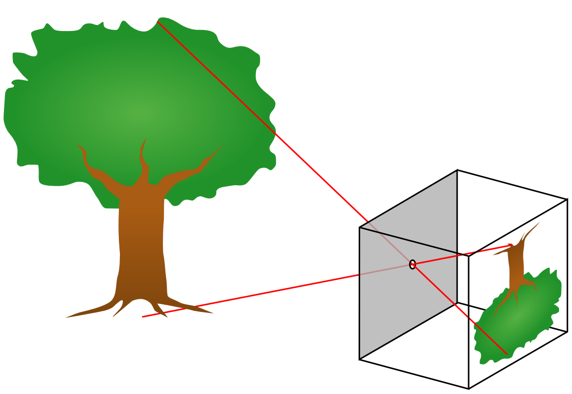
Pinhole Cameras



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Introduction

- pinhole cameras are simple optical devices that form images using a tiny aperture instead of a lens
- they demonstrate basic principles of image formation through rectilinear propagation of light

Components

- a light-tight box with a small pinhole on one side acts as the aperture
- an image screen or photographic surface is placed opposite the pinhole inside the box

Effective focal length

- the effective focal length f is defined as the distance between the pinhole and the image plane
- this distance determines the image size and sharpness
- increasing f enlarges the image but reduces brightness and sharpness due to diffraction

Image formation

- each point on an object emits light in all directions, but only rays passing through the pinhole reach the screen
- the result is an inverted, real image formed on the image plane
- no lenses are involved, so no refraction or chromatic aberration occurs

Image properties

- image is always real, inverted, and reduced or magnified depending on object distance and pinhole-to-screen distance
- image sharpness improves with a smaller pinhole but brightness decreases
- very small pinholes cause diffraction, blurring the image

Advantages and limitations

- advantages include simplicity, low cost, and infinite depth of field
- limitations include dim images, long exposure times, and limited resolution due to diffraction and small aperture size