Notice

- Your final homework (#13) is due tomorrow!
- This homework can still be collected from my office area in SER 220 from Friday 30th April onwards (for exam revision).
- Final exam Friday 7 May this room (BUS 318) from **9:30 - 11:20 am.**
- **Topics:**

  Magnets and Electromagnetism (Ch.14)

  Waves and acoustics (Ch.15)

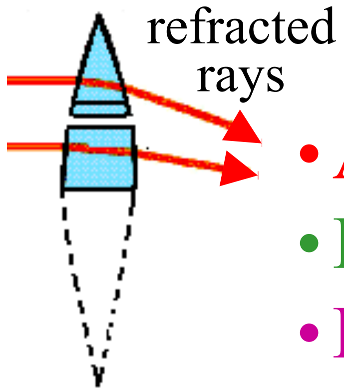
  Light and geometric optics (Ch. 16 and 17)

  (not including interference)

Lenses

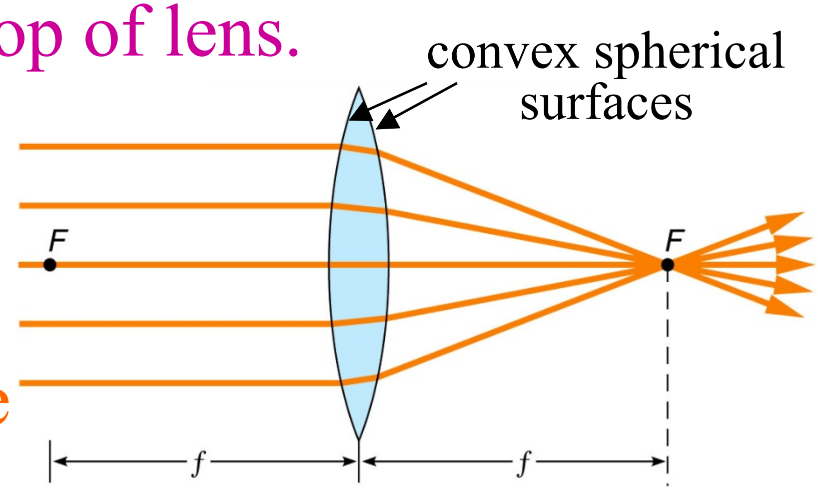
Question: How do lenses **form images**?

- Lenses are made of a transparent material: glass, quartz, etc.
- **Refraction** (bending) of **light rays** as they pass **through lens** is responsible for the resultant **size** and **nature** of the image.
- Two **types** of lenses: **positive** and **negative**.



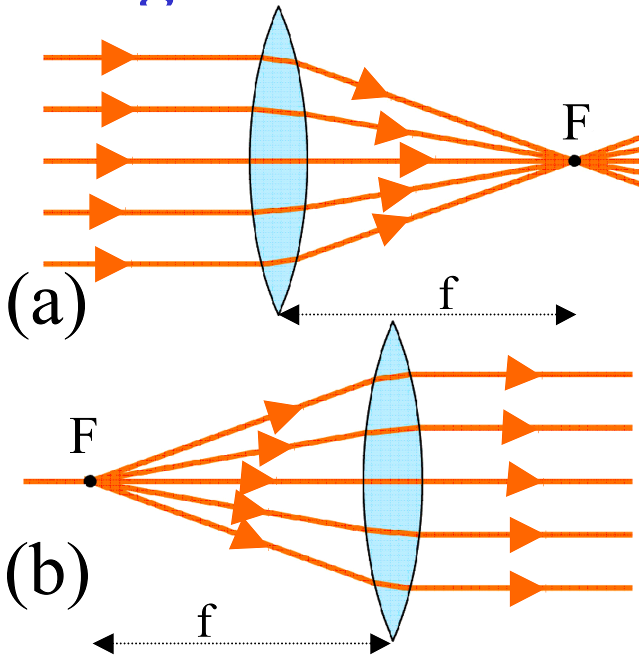
Positive lenses (convex):

- A positive lens causes the light rays to converge.
- Lens acts as a set of prisms.
- Prism angle larger at top of lens.



- Light at top of lens is bent more than light passing through it near the middle of the lens.
- Parallel rays are brought to a single point 'F' called the "**focal point**".

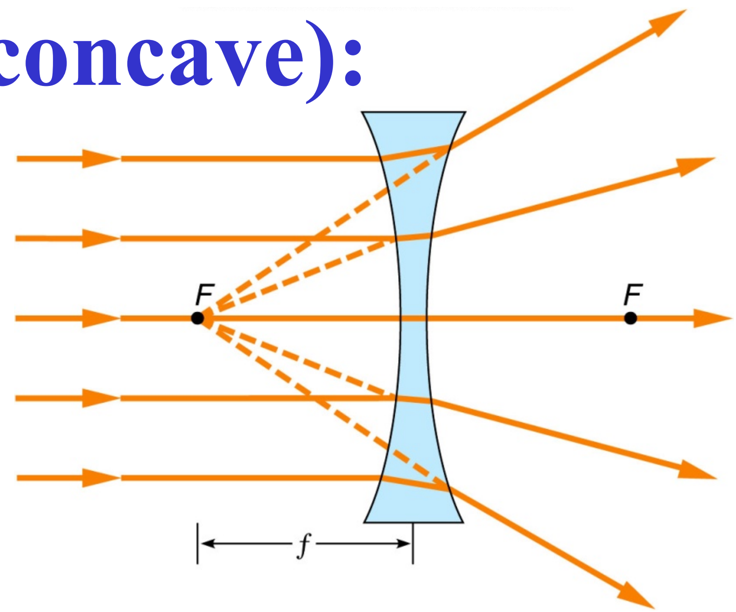
- Distance from **center** of **lens** to **focal point** is called **focal length 'f'**.



- **Focal length** is a **property** of an individual **lens** and depends on its **curvature** and **index of refraction**.
- There are **two focal points**, one on either side of the lens.
- **Light** is **reversible**:
  (a) **Parallel light** brought to a **focus**.
  (b) **Point light** at **focal point** creates a **parallel beam** of light (flash light).

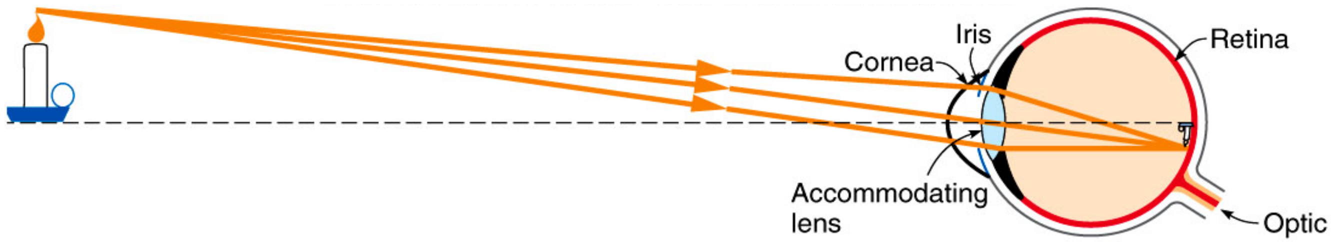
Negative Lens (concave):

- Acts like a set of **upside down prisms bending** light **away** from the optic axis.
- **Diverging rays** appear to **come** from a **common focal point** to the left of lens.



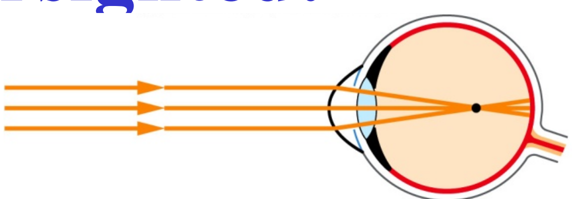
Eye Sight

- The **eye** contains **two positive lenses** (cornea) and accommodating lens.

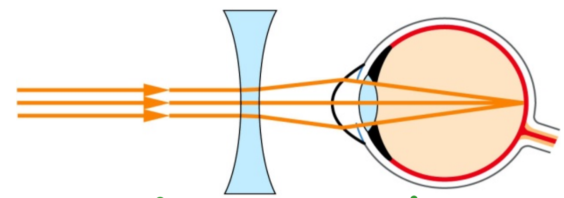


•A **real, inverted, minified** image is formed.

Nearsighted:

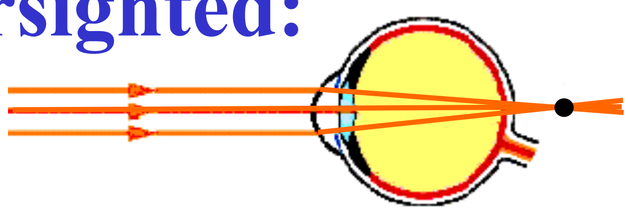


Parallel light focuses **in front** of retina

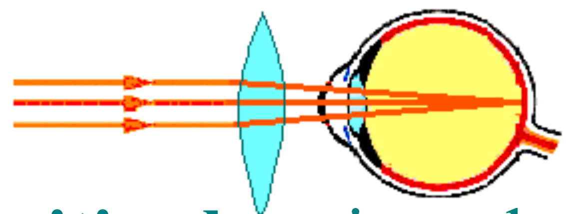


Negative lens introduces **divergence** to correct focus.

Farsighted:



Parallel light focuses **behind** retina

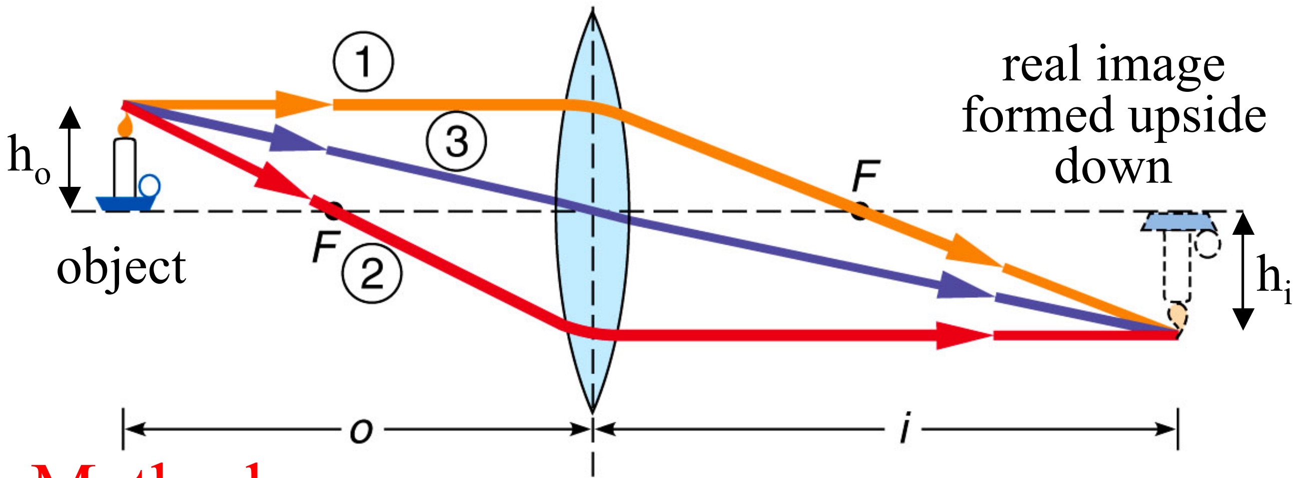


Positive lens introduces **convergence** to correct focus.

Image Formation Using Ray Tracing

- Simple ray tracing techniques can be used to tell us the position and size of the image formed by different lenses.

Example: (Convex lens)



Forms:

An **inverted real image** on the **opposite** side of lens.

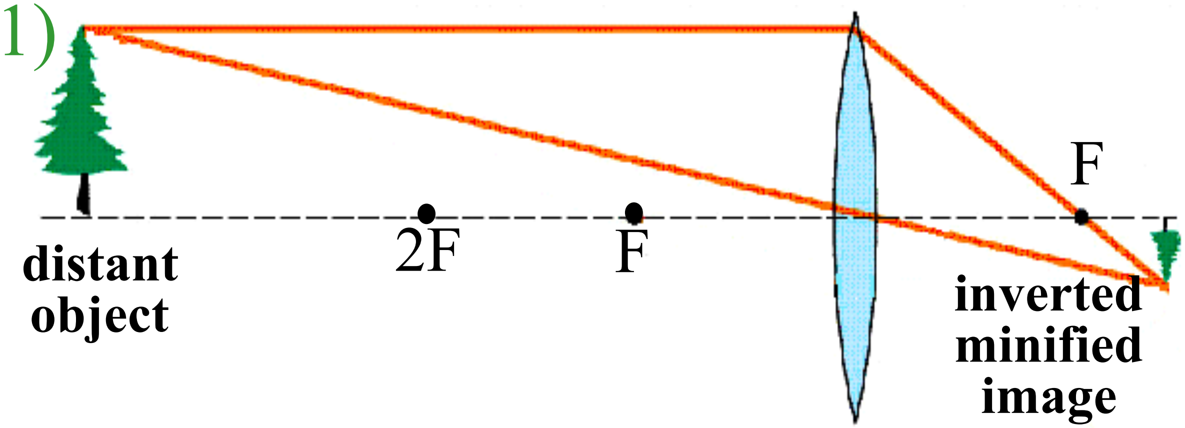
Method:

1. Draw a ray from top of object parallel to axis and then bend it so it passes through focal point.
2. Draw a ray passing through the focal point on the object (near) side and then make it emerge from lens parallel to axis.
3. Draw a ray from top of object passing straight through the center of the lens (undeviated).

Convex Lens Behavior

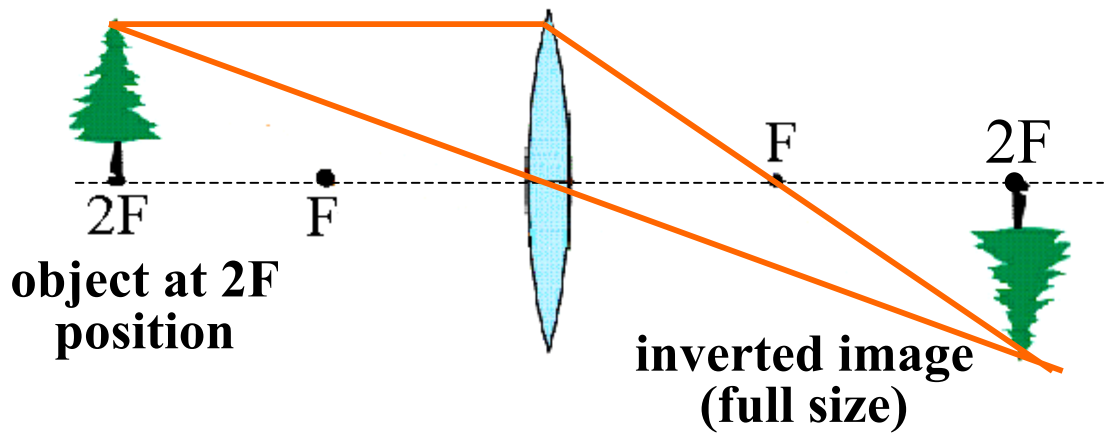
- **Three distinct regions** for objects:

1)



When object is **distant** (∞ to 2F) lens forms a **real, inverted image** (on right side) between F and 2F, the image is **minified**.

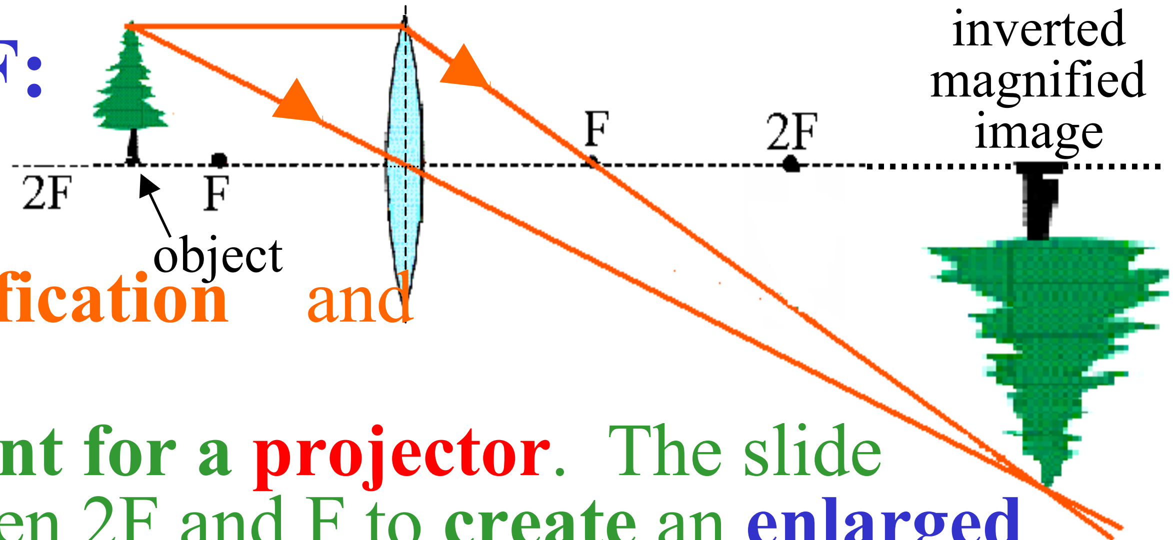
- This is how a **camera works** (or **eye**). The image is minified so that **large panoramas fit on film (retina)** so we get the "**big picture**".
- As it moves **closer** to lens **image increases** in size… until



- Object at 2F produces **symmetry**: **real image** is **full size**. This is the **optical set** up for a **photocopy machine**.

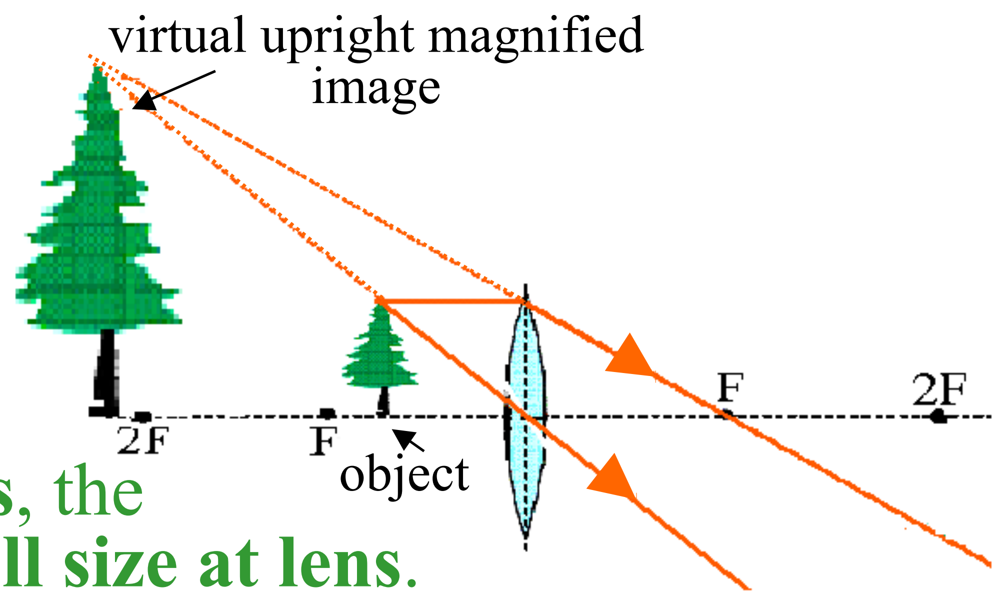
2) Between 2F and F:

- As object moves from 2F to F the **real image grows** in **magnification** and moves to right.



- This is the **arrangement for a projector**. The slide (film) is located between 2F and F to **create** an **enlarged** (but **inverted) image** on screen.
- When object **exactly at focal point**, the **image** will **blur** as **parallel light** is **produced**.

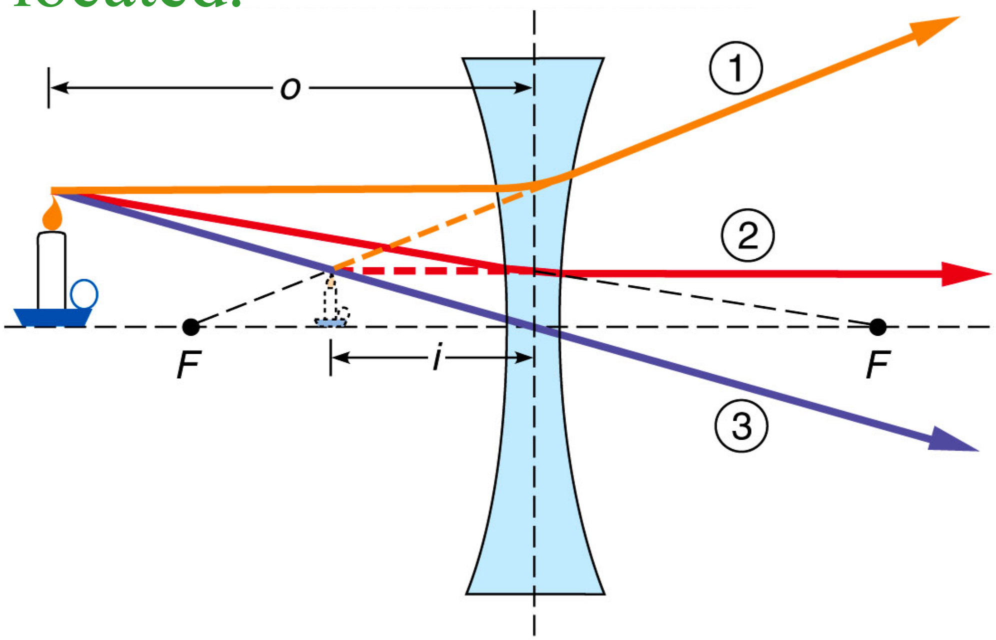
3) Between F and lens:



- This is a **magnifying lens** used to **enlarge print** with **image upright**.
- As object gets **closer to lens**, the **magnification reduces** to **full size at lens**.

Concave Lens Behavior

- A **concave lens operates** in only **one way**: it produces a **virtual, erect, minified** image… no matter where object is located.



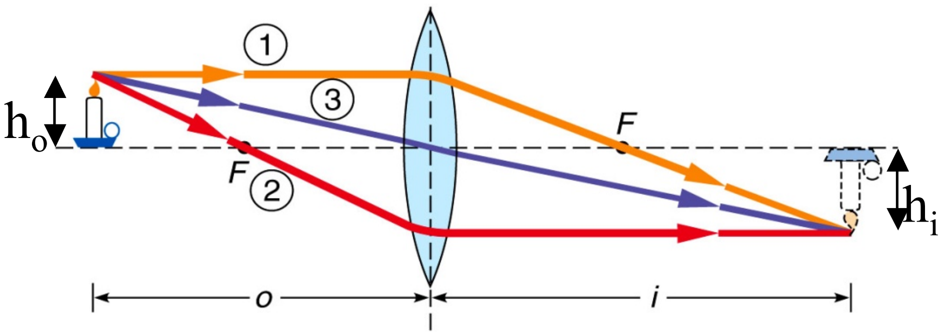
Rays diverging from **any object** are made to **diverge even more** by concave lens. Image is **always virtual** and gets smaller as object distance increases.

Summary:

- **Convex lenses** can form **magnified** or **minified inverted real** images, or **magnified right-side-up virtual** images.
- **Concave lenses** can **only** produce **minified, right-side-up virtual** images.

Determination of Image Position and Size (i.e. Magnification)

o = object distance from lens
i = image distance from lens
f = focal length of lens



- Then: $$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

Note: 'i' is -ve if a virtual image
'f' is -ve if diverging lens

- And: $$\text{magnification, } m = \frac{h_i}{h_o} = -\frac{i}{o}$$

Note: if 'm' +ve, image upright
if 'm' –ve, image inverted

Example: Object 5 cm in height located 40 cm to left of positive (convex) lens of focal length 25 cm.

Image distance 'i':

$$\frac{1}{i} = \frac{1}{f} - \frac{1}{o} = \frac{1}{25} - \frac{1}{40} = \quad 67\text{ cm}$$

Magnification 'm':

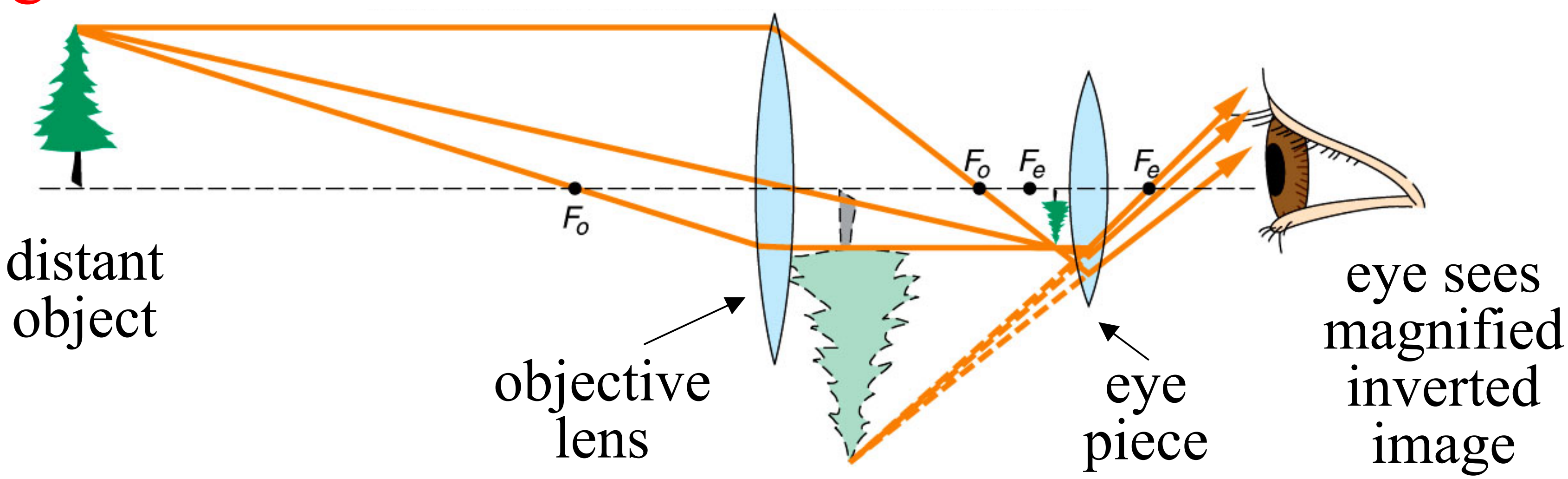
$$m = -\frac{i}{o} = -\frac{67}{40} = -1.7$$

Telescopes

- Invented in early 1600's in Holland.
- Combination of lenses – dramatic impact on astronomy.

Simple telescope:

- Consists of two positive lenses that **magnify** the angular image size.



- In astronomy objects are often very large but are extremely far away, so they appear small (i.e. small angular size).
- A telescope brings these objects closer to the eye where their angular size can be magnified.