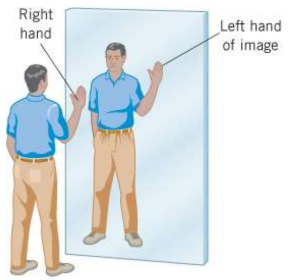
Physics 203 Ch. 34 Images
Instructor: Asa Bradley, MS, MFA

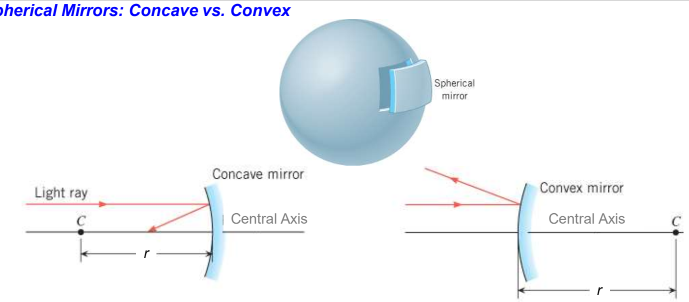
The Formation of Images by a Plane (Flat) Mirror



The person's right hand becomes the image's left hand.

The image properties:
1. It is upright.
2. It is the same size as the person (object).
3. The image is as far behind the mirror as the person (object) is in front.
4. The image is a **virtual** image.

Spherical Mirrors: Concave vs. Convex



If the inside surface of the spherical mirror is polished, it is a ***concave mirror.*** If the outside surface is polished, is it a ***convex mirror.***

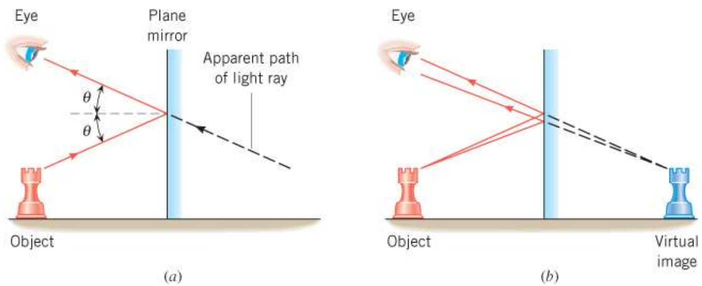
The law of reflection applies, just as it does for a plane mirror.

The ***central axis*** of the mirror is a straight line drawn through the center and the midpoint of the mirror.

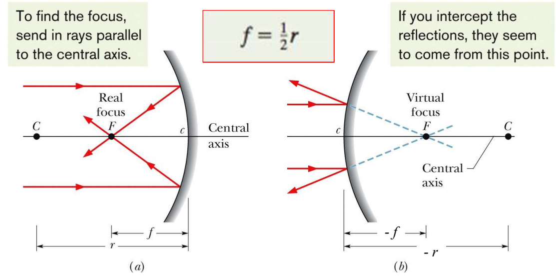
The Formation of Images by a Plane Mirror

A ray of light from the top of the chess piece reflects from the mirror. To the eye, the ray seems to come from behind the mirror.

Because none of the rays actually emanate from the image, it is called a **virtual image.**



Spherical Mirrors: Variables and Convention



Convention for direction (draw your pictures this way):

- Left of a mirror or a lens is positive.
  The "shiny" side of a mirror always points left, so left is "in front of" a mirror.
- Right of a mirror is negative and considered "behind."

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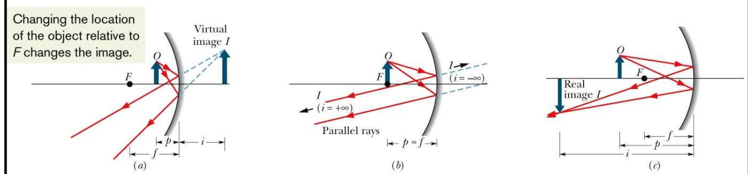
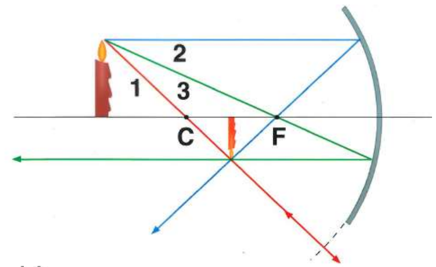
Spherical Mirrors: Type of Images



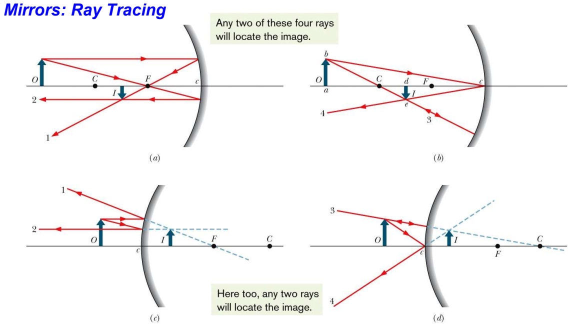
- A concave mirror can form a **real image** (if the object is outside the focal point) or a **virtual image** (if the object is inside the focal point).
- A convex mirror can form only a **virtual image**.
- The mirror equation relates an object distance *p*, the mirror's focal length *f* and radius of curvature *r*, and the image distance *i*: $\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$
- The magnitude of the lateral magnification m of an object is the ratio of the image height h' to object height h, (*Note: if h or h' are inverted, they are neg.*) $|m| = \frac{h'}{h}$ → $m = -\frac{i}{p}$

Concave Mirrors



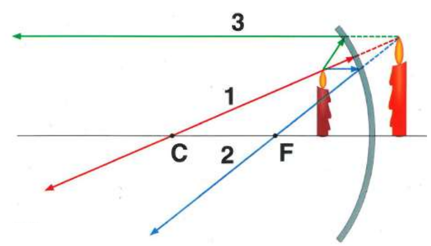
When an object is located beyond the center of curvature, a *smaller*, *inverted*, and *real* image is produced.

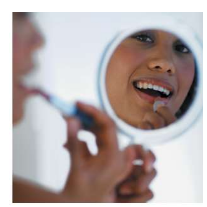
Spherical Mirrors: Ray Tracing



1. A ray that is initially parallel to the central axis reflects through the focal point *F* (ray 1 in Fig. a).
2. A ray that reflects from the mirror after passing through the focal point emerges parallel to the central axis (Fig. a).
3. A ray that reflects from the mirror after passing through the center of curvature *C* returns along itself (ray 3 in Fig. b).
4. A ray that reflects from the mirror at point *c* is reflected symmetrically about that axis (ray 4 in Fig. b).

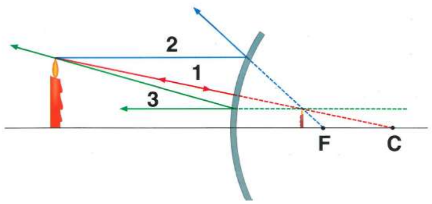
Concave Mirrors




(b)

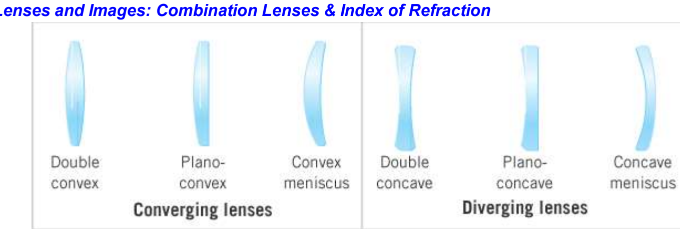
When an object is located between the focal point and a concave mirror, a *magnified*, *upright*, and *virtual* image is produced.

Convex Mirrors



Convex mirrors can only form *virtual* images. The image is *smaller* in size and *upright*.

Lenses and Images: Combination Lenses & Index of Refraction



For an object in front of a lens, object distance p and image distance i are related to the lens's focal length f, index of refraction n, and radii of curvature r_1 and r_2 by

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \text{(thin lens in air)},$$

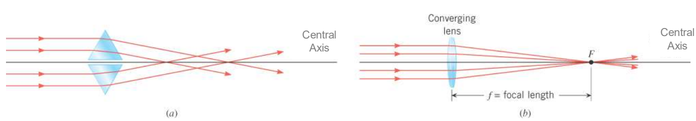
which is often called the **lens maker's** equation. Here r_1 is the radius of curvature of the lens surface nearer the object and r_2 is that of the other surface. If the lens is surrounded by some medium other than air (say, corn oil) with index of refraction n_{medium}, we replace n in above Eq. with n/n_{medium}.

A lens can produce an image of an object only because the lens can bend light rays, but it can bend light rays only if its index of refraction differs from that of the surrounding medium.

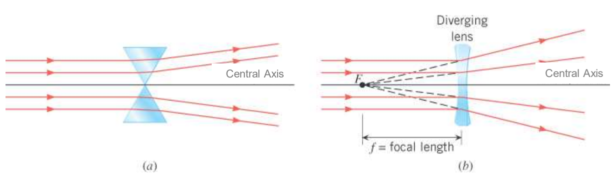
Lenses and images

You can also form images by refracting light.

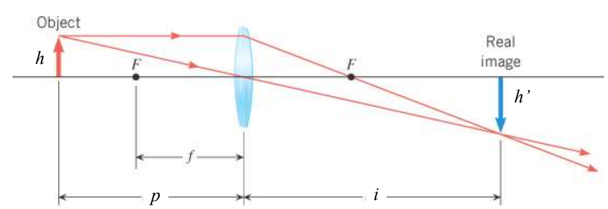
With a converging lens, paraxial rays that are parallel to the central axis converge to the focal point.



With a diverging lens, paraxial rays that are parallel to the central axis appear to originate from the focal point.



Lenses: The Thin-Lens Equation & the Magnification Equation

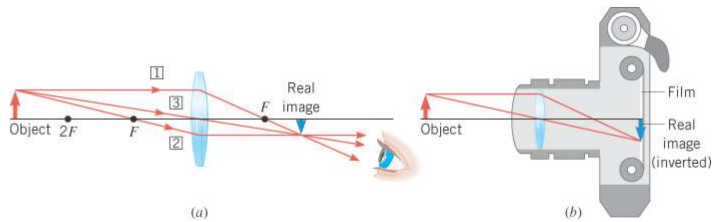


$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

$$|m| = \frac{h'}{h} \Rightarrow m = -\frac{i}{p}$$

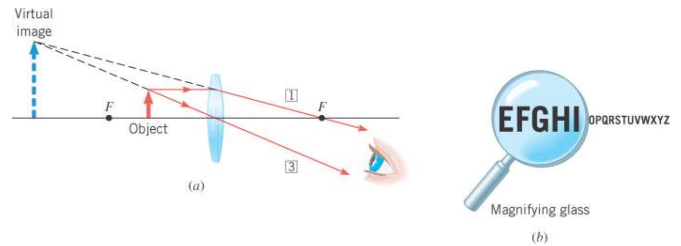
If the image is inverted, then the image height is negative.

The Camera



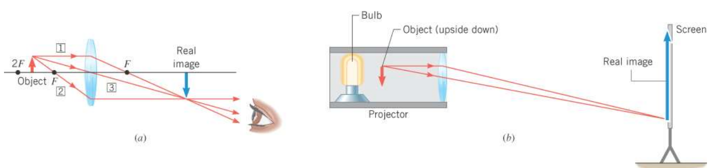
When the object is placed further than *twice the focal length* from the lens, the real image is inverted and smaller than the object.

Magnifying Glass



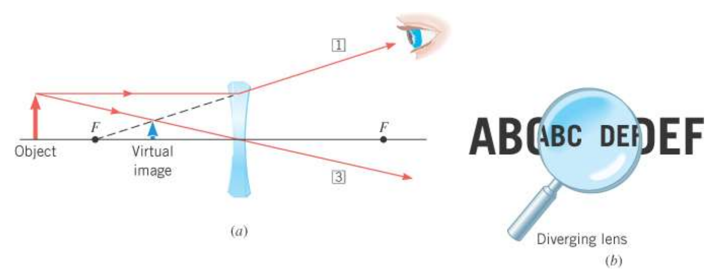
When the object is placed between F and the lens, the virtual image is upright and larger than the object.

Film Projector



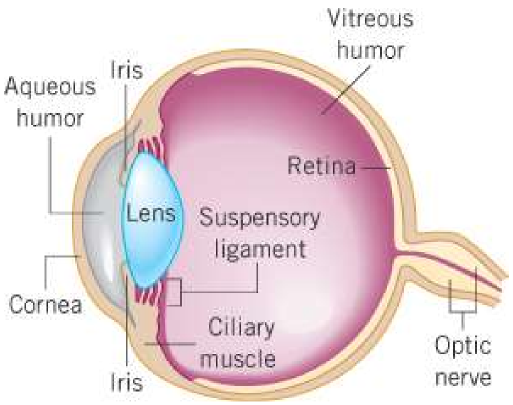
When the object is placed *between F and 2F*, the real image is inverted and larger than the object.

Images formed by Diverging Lenses



A diverging lens always forms an upright, virtual, diminished image.

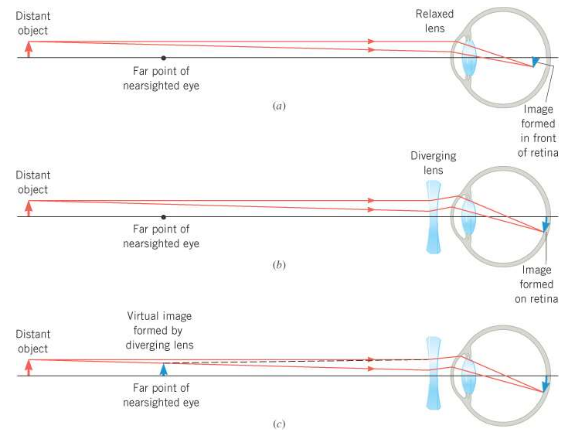
Anatomy of The Human Eye



Air n = 1.00
Cornea n = 1.38
Aqueous Humor n = 1.83
Lens n = 1.40 (average)
Vitreous Humor n = 1.34

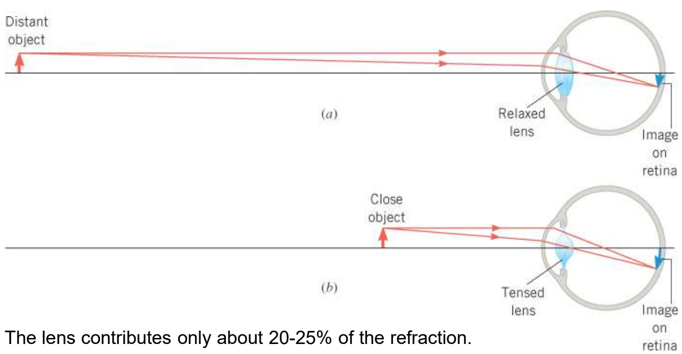
About 70% of refraction happens at air/cornea border.

Myopia – Nearsightedness



The glass lens creates an image of the distance object at the far point of the nearsighted eye.

The Function of the Lens of the Eye

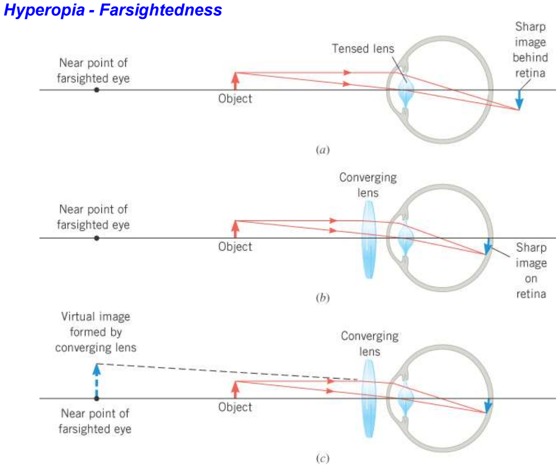


The lens contributes only about 20-25% of the refraction.

Near point = nearest point where eye can focus.
20's → 25 cm 40's → 50 cm 60's → 500 cm

Far point = furthest point where eye can focus.
Normal eyesight → infinity

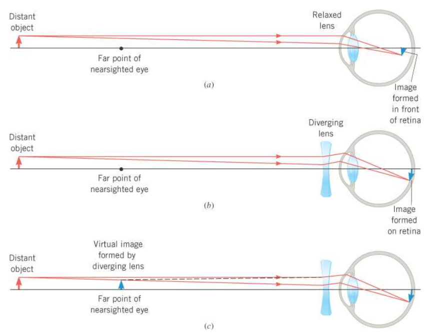
Hyperopia - Farsightedness



The glass lens creates an image of the close object at the near point of the farsighted eye.

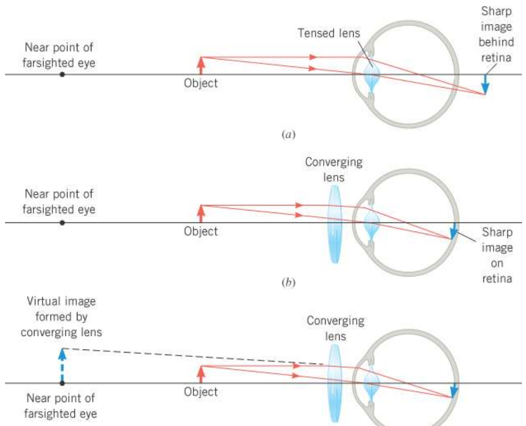
Eyeglasses for the Nearsighted Person

A nearsighted person has a far point located only 521 cm from the eye. Assuming that eyeglasses are to be worn 2 cm in front of the eye, find the focal length needed for the diverging lens of the glasses so the person can see distant objects.



Contacts for the Farsighted Person

A farsighted person has a near point located 210 cm from the eyes. Find the focal length and the "power" of the lenses of a pair of contacts that can be used to read a book held 25.0 cm away from the eyes.

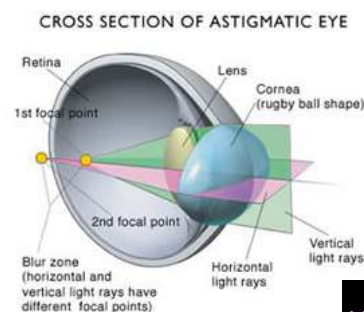


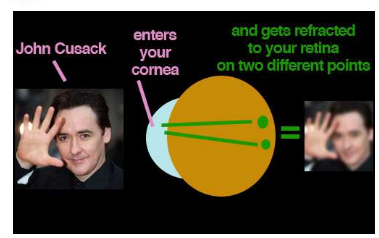
The Refractive Power of a Lens – The Diopter

Optometrists who prescribe correctional lenses and the opticians who make the lenses do not specify the focal length. Instead they use the concept of ***refractive power*** or just ***power.***

$$\text{Refractive power (in diopters)} = \frac{1}{f\,(\text{in meters})}$$

Astigmatism: Cornea (and eye) like a football instead of a soccer ball





Reading your prescription: Glasses

Glasses RX:

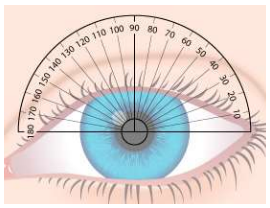
Purpose: Full Time Wear

	Sph	Cyl	Axis	Add
OD	-0.25	-1.00	087	
OS	0.00	-1.25	090	

OS = Oculus Sinister, Left Eye
OD = Oculus Dextrus, Right Eye

(Spherical) Diopter
Neg = nearsighted
Pos = farsighted

Cylinder is the degree of astigmatism measured in diopters. The power added is not spherical. One meridian has no added curvature, and the meridian perpendicular to this "no added power" meridian contains the maximum power and lens curvature to correct astigmatism



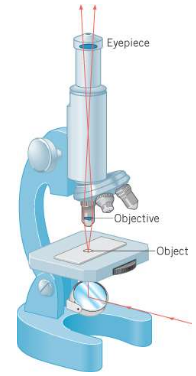
Axis describes the lens meridian that contains no cylinder power to correct astigmatism.
90 = vertical meridian
180 = horizontal meridian

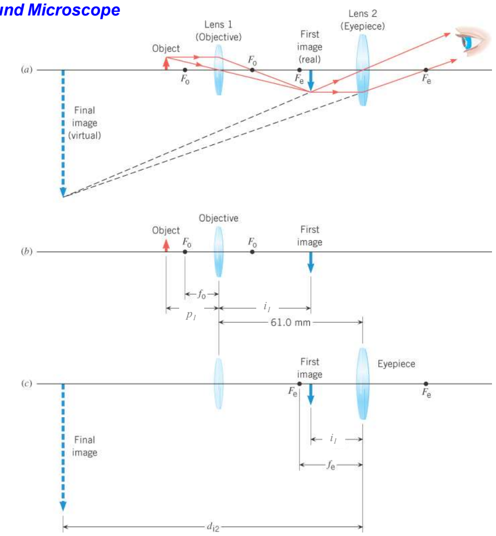
The axis is the lens meridian that is 90 degrees away from the meridian that contains the cylinder power.

Optical Instruments: Compound Microscope

The image produced by one lens serves as the object for the next lens.

Apply equations twice.





Reading your prescription: Contacts

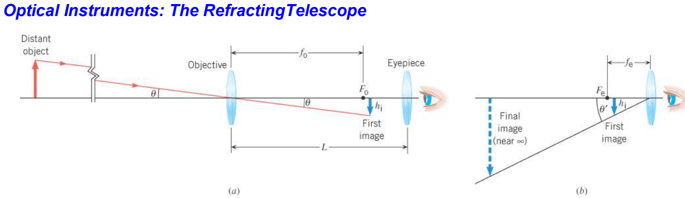
Contact Lens Rx

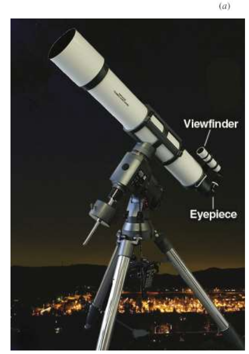
	BASE CURVE	LENS RX	SIZE
O.D.	8.60	0.00-1.25x090	14.5
O.S.	8.60	0.00-1.25x090	14.5

A contact lens prescription must specify the base (central) curve of the back surface of the contact lens, the lens diameter, and the specific manufacturer and brand name of the lens.

The power is usually modified, compared to the glasses, prescription, because of the small distance from the eye to the contact lens.

Optical Instruments: The RefractingTelescope

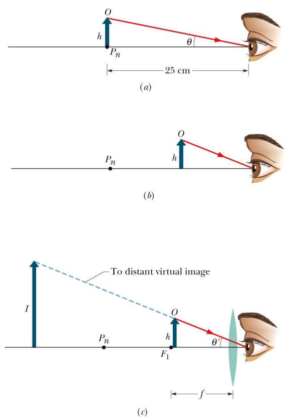




The view finder is a separate small telescope used to locate the object.

The observer looks through the eyepiece to see the full magnification of the telescope.

Optical Instruments: The Angular Magnifier



(a) Shows an object O placed at the near point P_n of an eye. The size of the image of the object produced on the retina depends on the angle θ that the object occupies in the field of view from that eye.

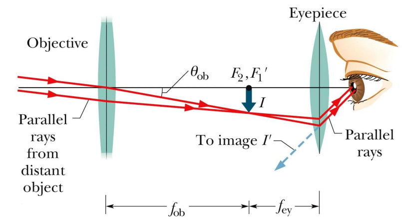
(b) Moving the object closer is the same as increasing the angle and increasing the magnification, but now the object is not in focus since it's closer than the near point.

(c) You can restore the clarity by looking at the through a converging lens, which you already know. This is just a different way to approximating the magnification of the lens.

Using 25 cm as a reference near point, the angular magnification of a simple magnifying lens is:

$$m_\theta \approx \frac{25\text{ cm}}{f}$$

Optical Instruments: The Telescope Revisited

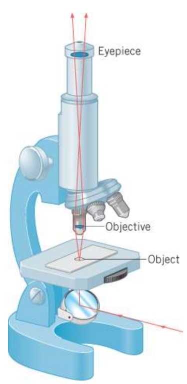


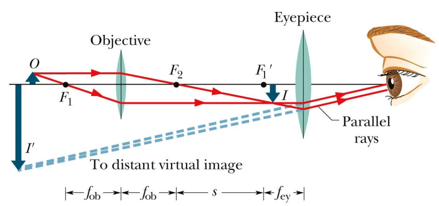
The lens arrangements for telescopes and for microscopes are similar, but telescopes are designed to view large objects at large distances. This difference requires that in the telescope the second focal point of the objective F_2 coincide with the first focal point of the eyepiece F'_1.

The angular magnification of a refracting telescope is:

$$m_\theta = -\frac{f_{ob}}{f_{ey}}.$$

Optical Instruments: Compound Microscope Revisited





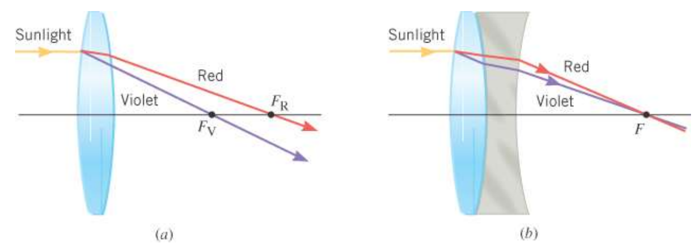
$$M = m m_\theta = -\frac{s}{f_{ob}}\frac{25\text{ cm}}{f_{ey}}$$

s is the tube length and m_θ is the angular magnification of the eye piece

$$m_\theta \approx \frac{25\text{ cm}}{f}$$

using 25 cm as a reference value for the near point

Things to Worry About with a Refraction Telescope: Lens Aberrations



Chromatic aberration: different colors are focused at different points along the principal axis.