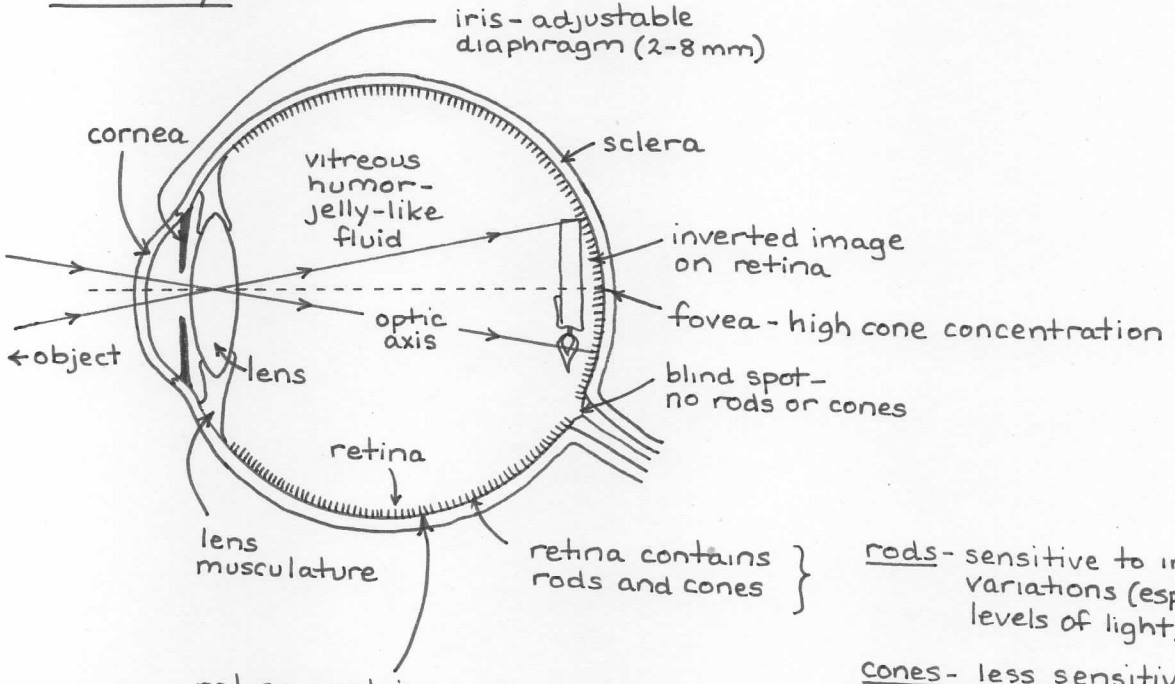
OPTICAL INSTRUMENTS

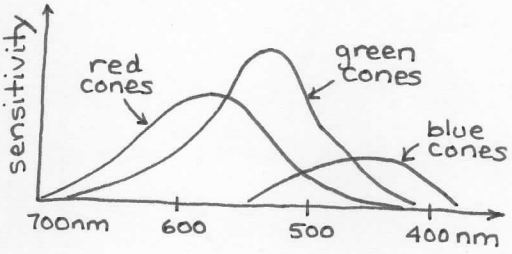
human eye



rods - sensitive to intensity variations (esp. at low levels of light)

cones - less sensitive than rods to intensity variations; sense color

3 types



* optic nerve - conduit for image information to brain; can respond to light variations in $\frac{1}{30} - \frac{1}{60}$ second

* lens is flexible and shape is changed by tension applied by attached muscles

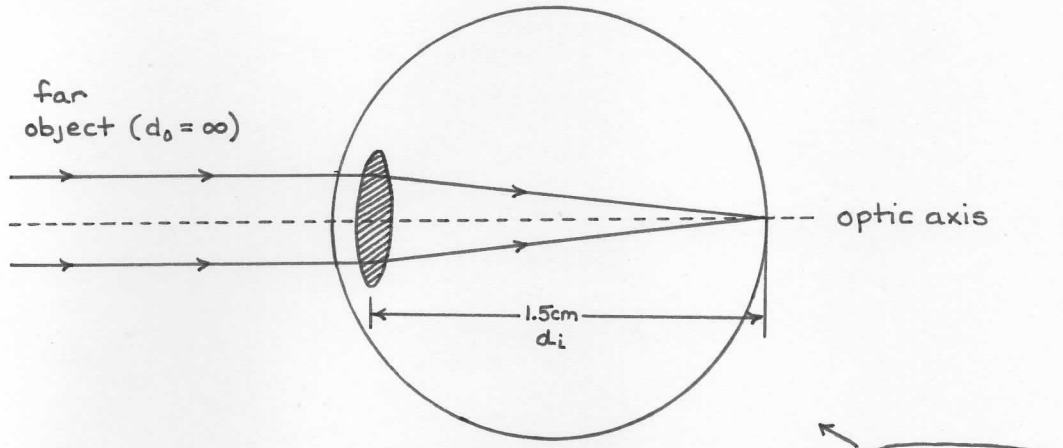
power of lens	distance to object	muscle activity
20D	∞	relaxed
30D	near (~20 cm)	active

accommodation (of a lens) - the adjustment of the lens between near and far objects

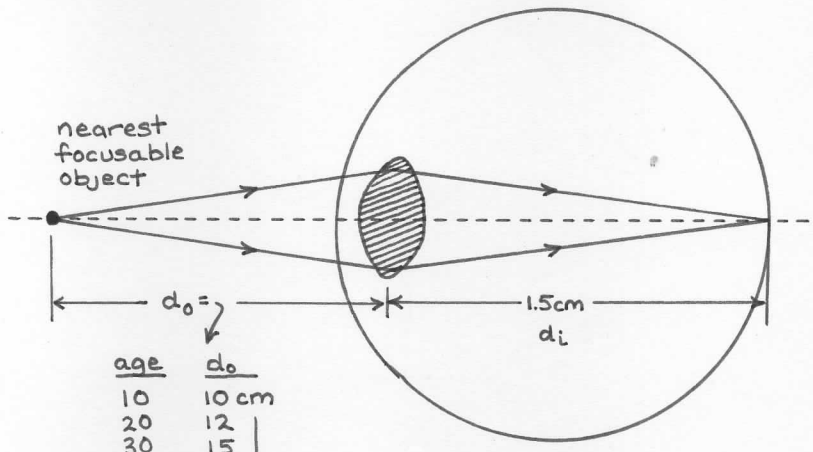
note difference

camera		eye
* lens shape fixed	⟺	* image distance fixed
* image distance d_i varied		* lens shape changed

vision



typically good vision

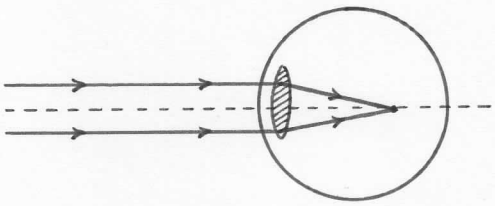


age	d_o
10	10 cm
20	12
30	15
40	25
50	40
60	100

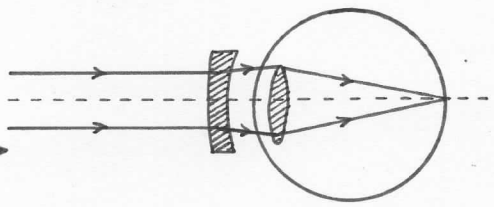
near point - the minimum d_o for which an object can be properly focused on the retina; depending on a person's age, the normal range is from 10cm to 1.0 m.

far point - the maximum d_o for which an object can be properly focused on the retina; the normally "good" value would be ∞.

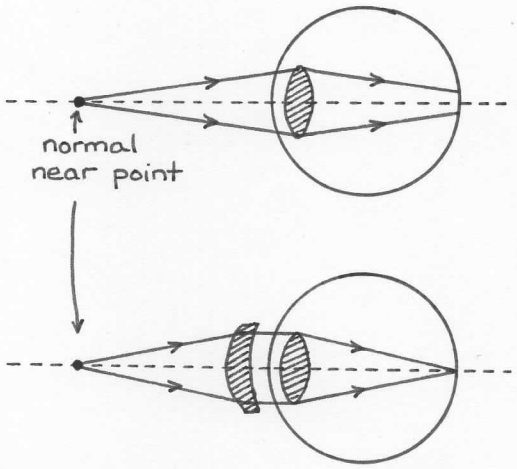
nearsightedness (myopia) - condition in which a person's far point is not at ∞, but nearer; very distant objects cannot be focused on the retina; this is due to (1) a lens that cannot become "thin" enough, or (2) a "long" eye



* correct with a diverging lens!



farsightedness (hyperopia) - condition in which a person's far point may be at ∞, but there near point is farther out than some appropriate value; this is due to: (1) the lens not being able to assume enough curvature, or (2) a "short" eye.

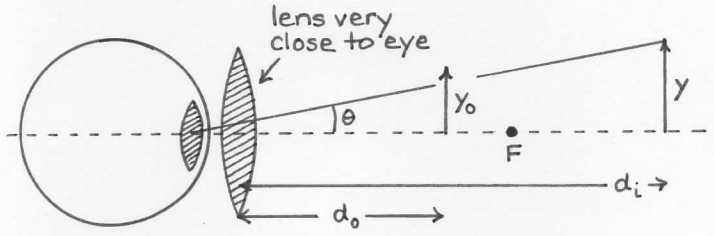


* correct with a converging lens

eg The far point of a person with myopia is 78 cm, and his near point is 23 cm. What power must the corrective lens have if it is to correct his far point → ∞? How will the correction change his near point? Assume the lens will be 3 cm in front of the eye.

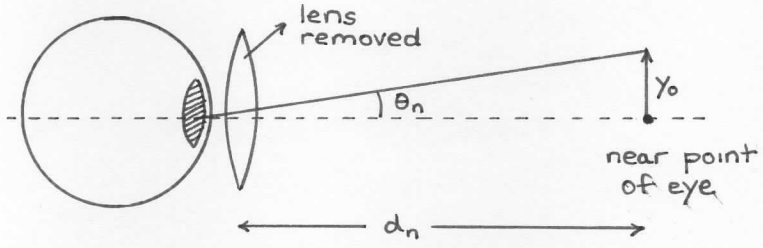
astigmatism - a vision defect in which a point source cannot be focused to a point because of the cornea or the lens being non-spherical; usually corrected by a lens with a cylindrically modified surface.

magnifying glass (simple microscope)



θ = angular size of image

$\theta = \tan^{-1}\frac{y}{d_i} = \frac{My_o}{d_i}$



$\theta_n = \tan^{-1}\frac{y_o}{d_n}$

* if θ (θ_n) is small, then $\theta \approx \frac{My_o}{d_i}$ $\left(\theta_n \approx \frac{y_o}{d_n}\right)$

(near point) angular magnification ➡ $m \equiv \frac{\theta}{\theta_n}$

$$m \approx \frac{M y_o}{d_i} \Big/ \frac{y_o}{d_n} = M \frac{d_n}{d_i} = \left(\frac{d_i}{d_o}\right) d_n / d_i = \frac{d_n}{d_o}$$

lateral magnification (use magnitude only)

thus $\boxed{m \approx \frac{d_n}{d_o}}$ ← seems to imply that m can be made arbitrarily large if d_o is made arbitrarily small!

* what's wrong with this?

* if image is to be located at near point, $d_i = d_n$ and

$d_o = \frac{d_n f}{d_n - f}$ ... substitute into $m \approx \frac{d_n}{d_o}$ to get

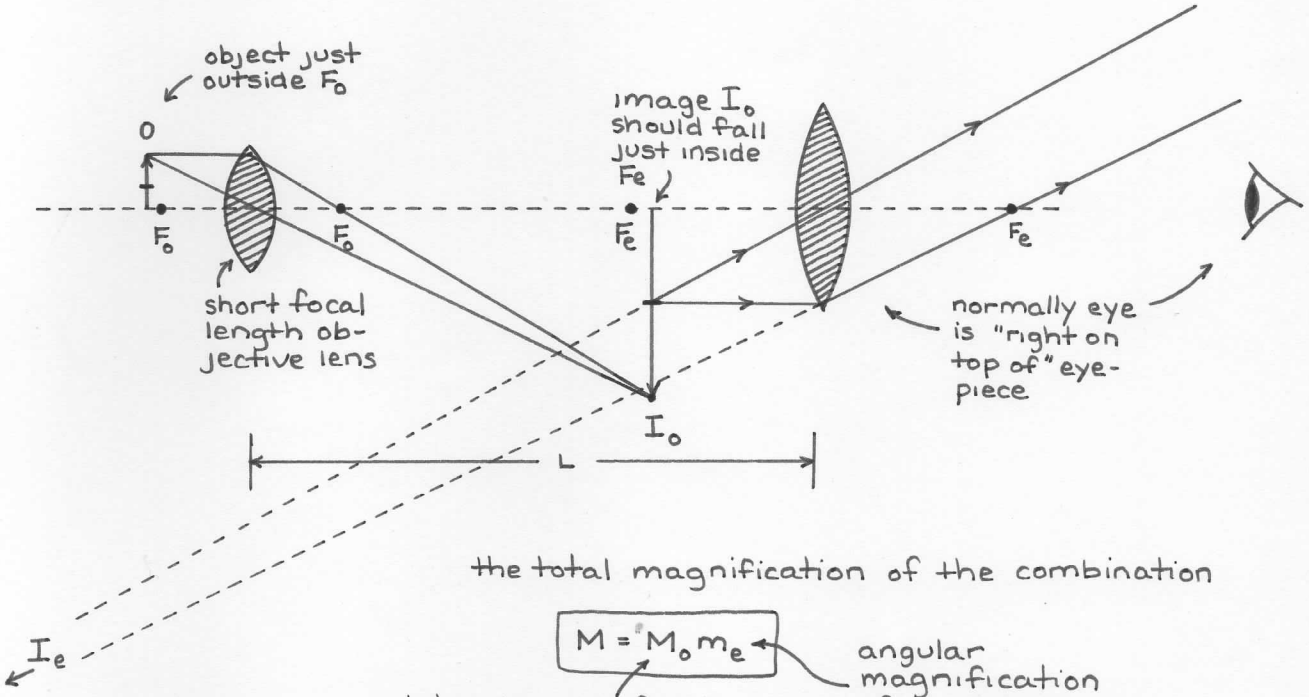
$\boxed{m \approx 1 + \frac{d_n}{f}}$ where object must be placed at $d_o = \frac{d_n f}{d_n - f}$

* if image is to be located at $d_i = \infty$, then

$\boxed{m \approx \frac{d_n}{f}}$

eg Use a converging lens w/ f = 12 cm as a magnifying glass. If your near point is 15 cm, find the lens's maximum angular magnification. Find the magnification for relaxed eye viewing.

compound microscope



the total magnification of the combination

$$M = M_o m_e$$

M_o: lateral magnification of objective lens

m_e: angular magnification of eyepiece

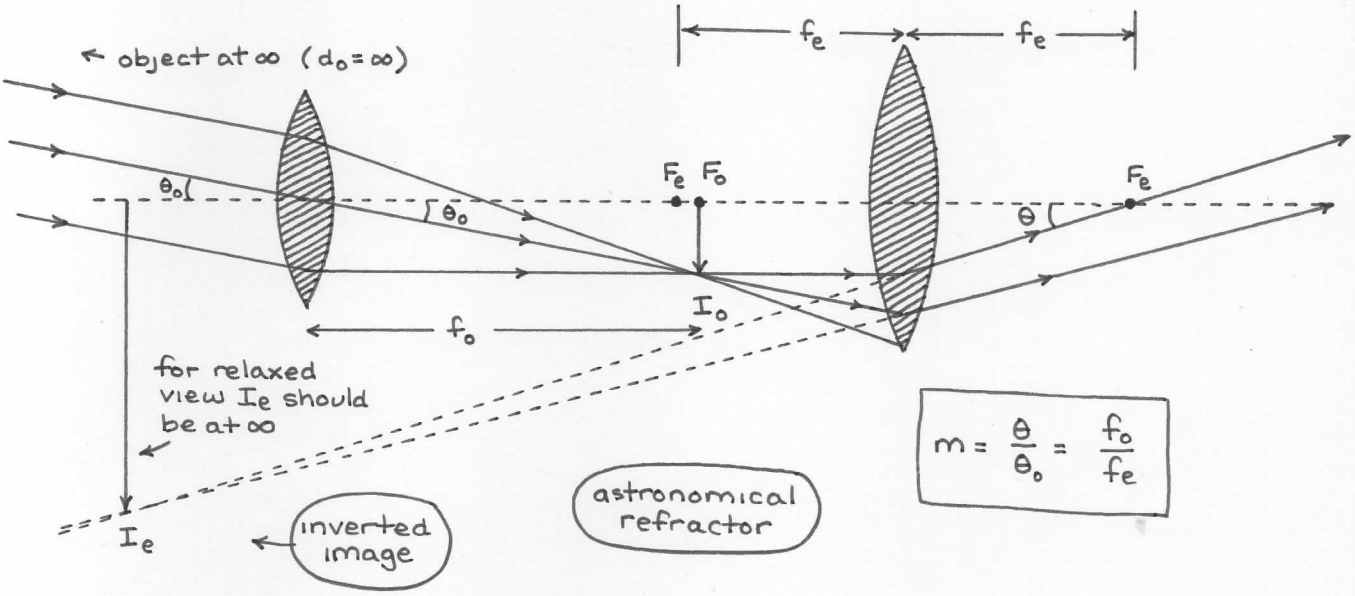
$$M_o = \frac{f_o}{d_o - f_o} \approx \frac{L}{f_o} \text{ if } L \approx d_i \qquad \text{and} \qquad m_e = 1 + \frac{d_n}{f_e} \text{ or } \frac{d_n}{f_e} \leftarrow \text{image at } \infty$$

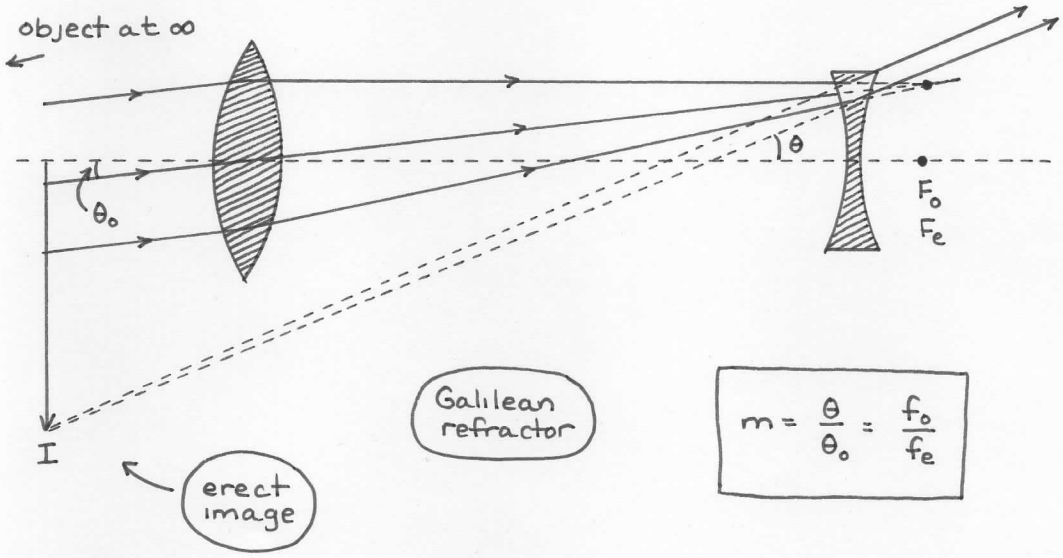
(m_e: image at near point)

$$M \approx \left(\frac{L}{f_o}\right)\left(\frac{d_n}{f_e}\right) \qquad \boxed{M \approx \frac{L d_n}{f_o f_e}}$$

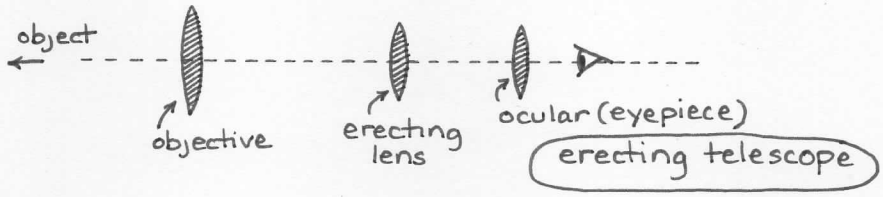
eg A compound microscope has an objective lens w/ a focal length of 10mm and an eyepiece w/ a focal length of 4.0 cm. The lenses are fixed at 20 cm apart in the barrel. Determine the approximate total magnification for the microscope.

refracting telescopes (refractors)

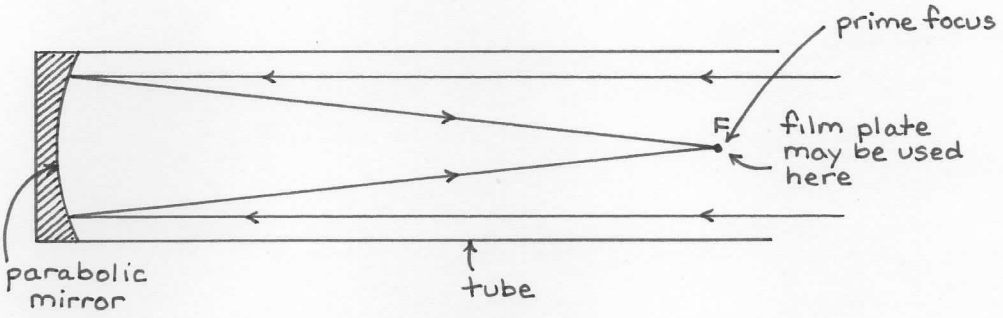


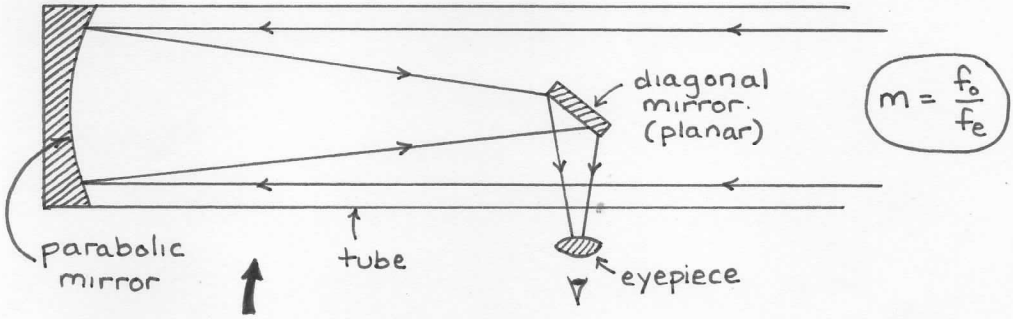


* Galileo built in 1609 after hearing about similar instrument built by H. Lipschey (Dutch)

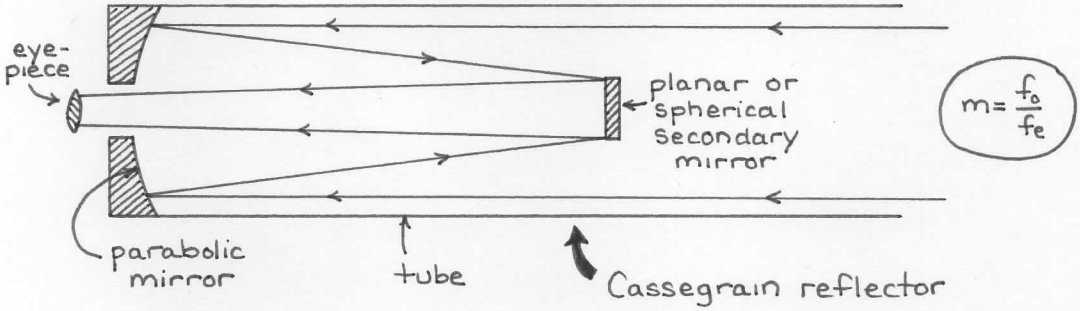


reflecting telescopes (reflectors)



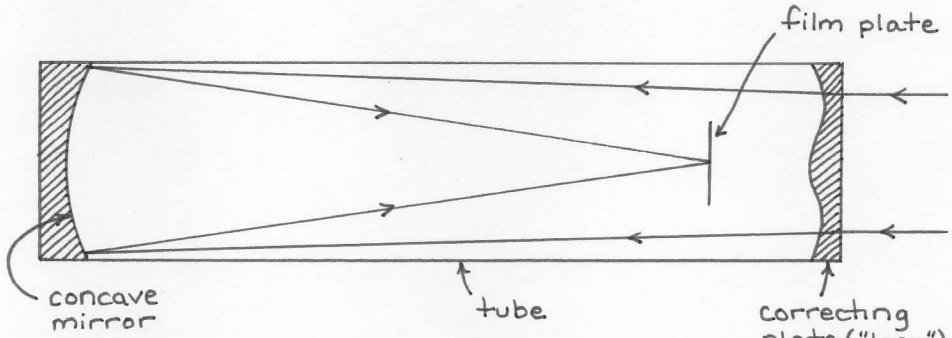


Newtonian reflector



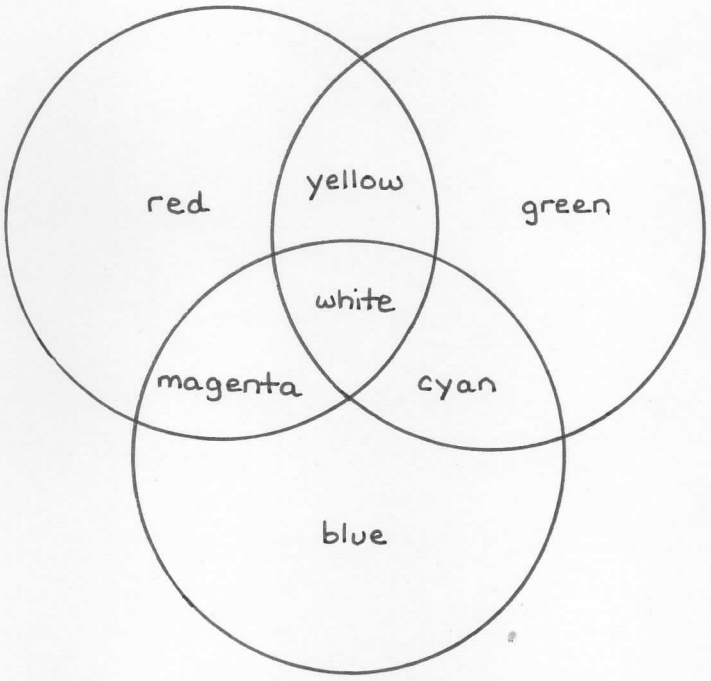
Cassegrain reflector

hybrid telescope



Schmidt telescope

Color



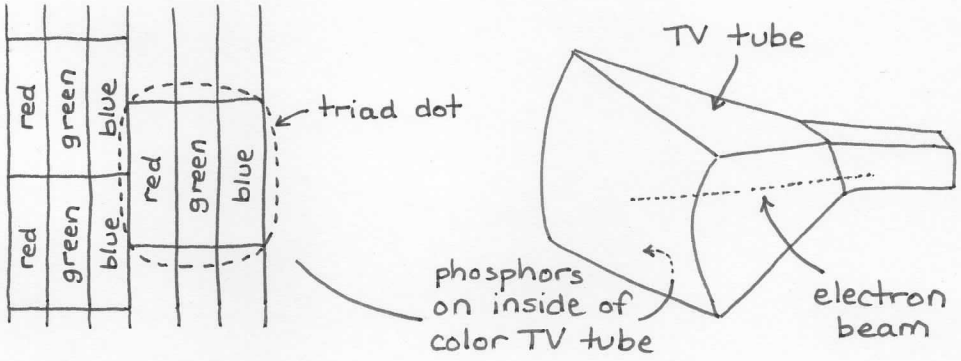
mixing light

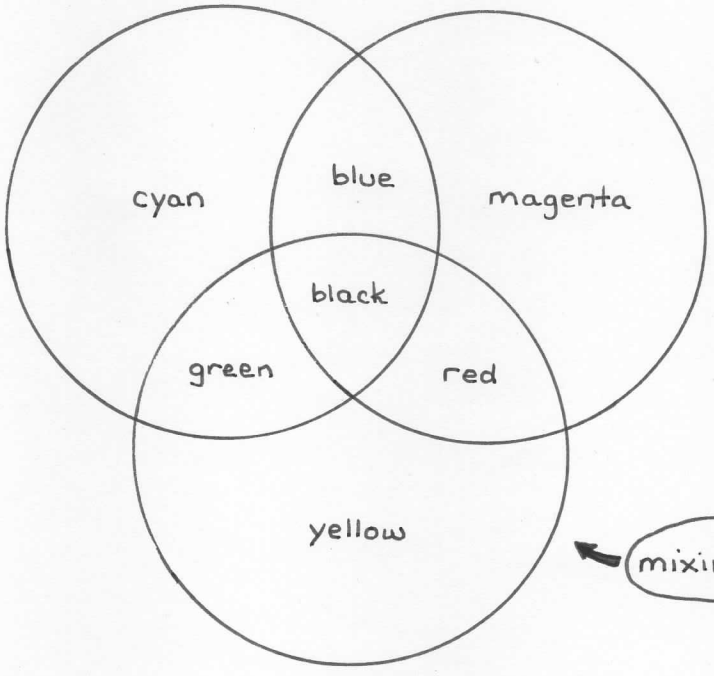
additive method of color production

additive primaries

red
green
blue

* triad dots consisting of 3 phosphors (RGB) are used to produce color images





subtractive method of color production

subtractive primaries

cyan
magenta
yellow

mixing pigments