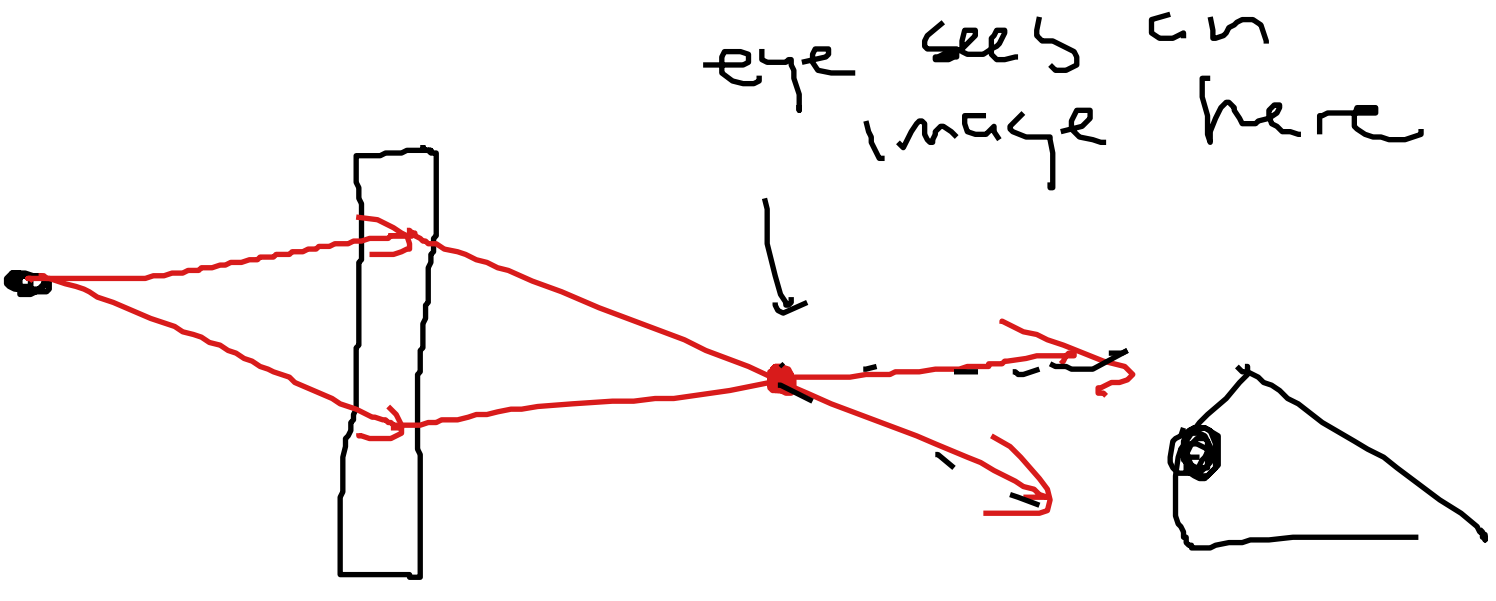
Real Image



converging device

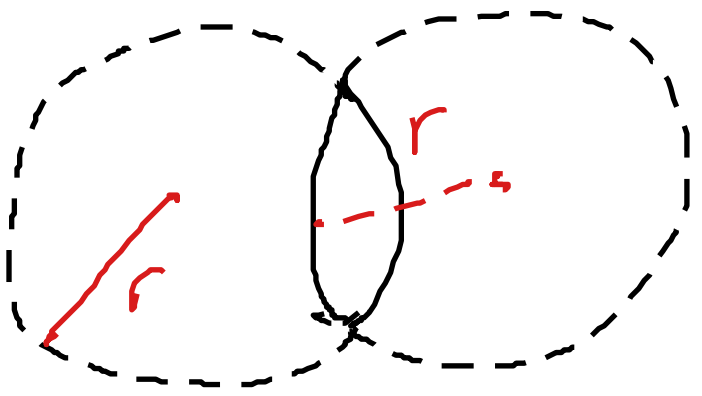
rays really do come from the image

(Virtual Image: they only seem to)

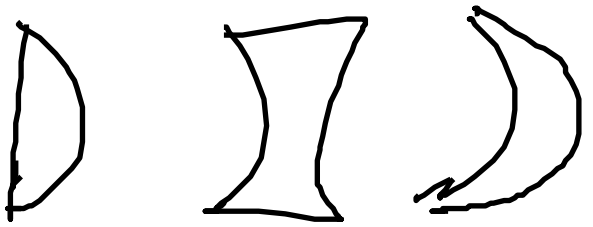
- Real images can be projected onto a screen,
- Real images are inverted

Thin Spherical Devices

lens

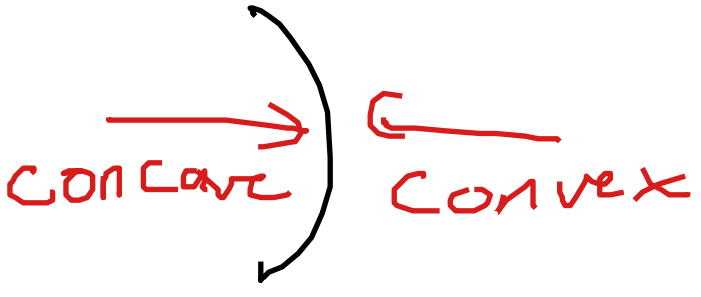


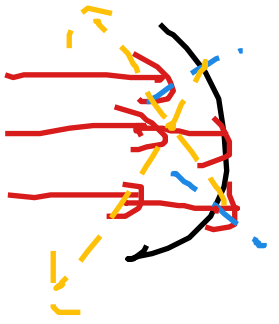
- surfaces are portions of spheres
- width of lens small compared to radii of spheres



convex lens

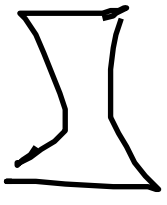
mirror

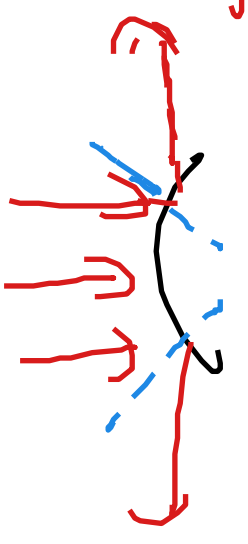




converging devices

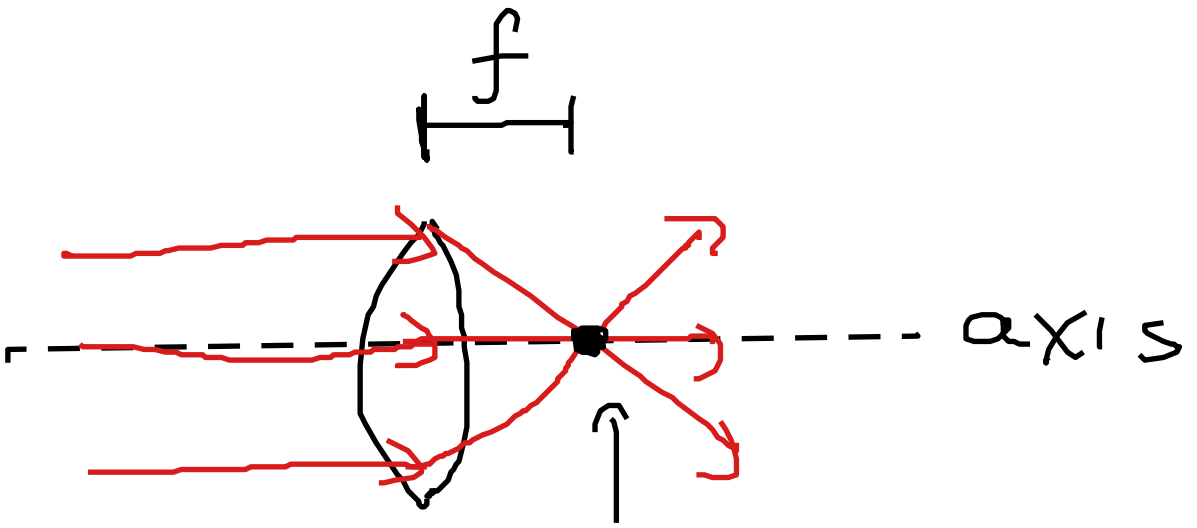
make rays converge (or diverge less)





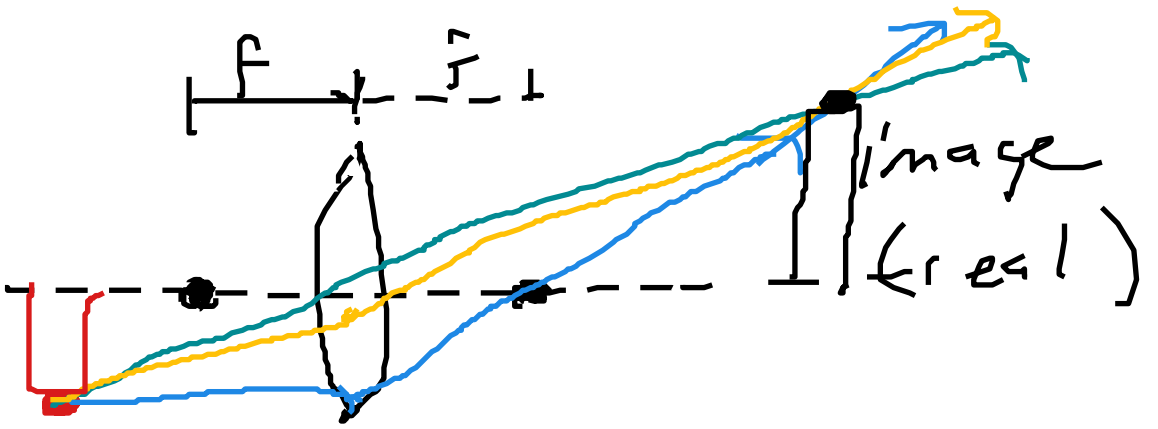
diverging devices

Convex Lens



f : Focal length of lens

(Smaller f, stronger lens)



object

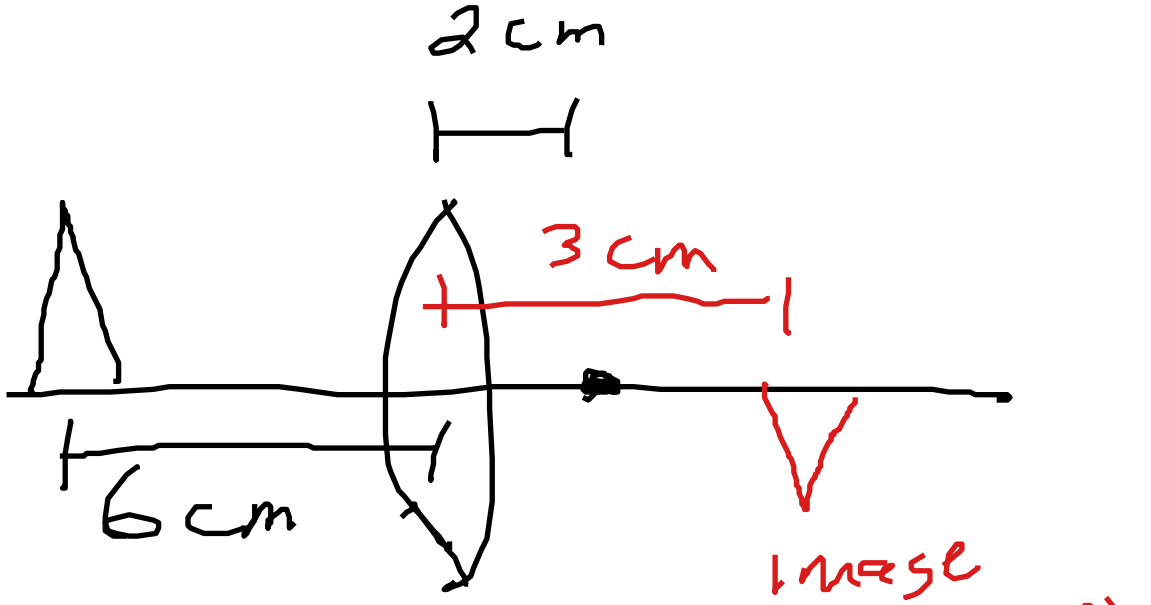
A ray which is parallel to the axis passes through the focal point on the other side

A ray which passes through center of lens isn't bent

Lens Equation

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- d_o: distance from object to lens
- d_i: " " image to lens
- f: focal length



Find d_i?

$$\frac{1}{2} = \frac{1}{6} + \frac{1}{d_i}$$

$f = 2$

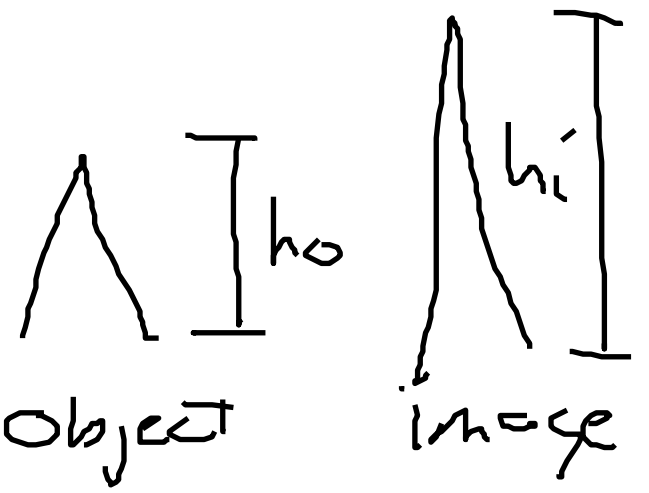
$d_o = 6$

$$\frac{1}{3} = \frac{1}{2} - \frac{1}{6} = \frac{1}{d_i}$$

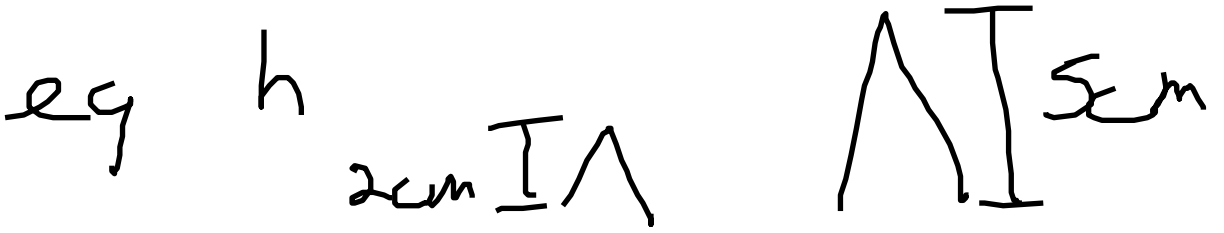
$$\rightarrow d_i = \underline{3\,cm}$$

Magnification

$$M \equiv \frac{h_i}{h_o}$$

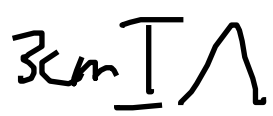


eg



$$M = \frac{5\,cm}{2\,cm} = 2.5$$

If image is inverted, $h_i < 0$

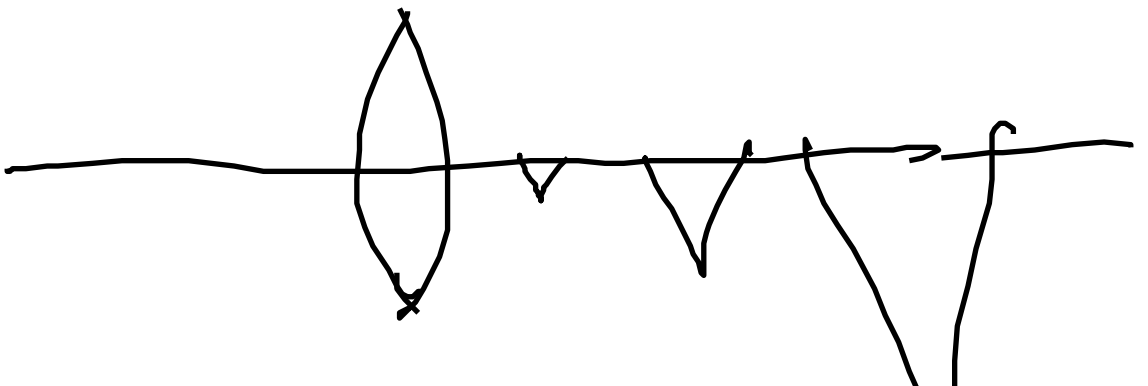


$$M = \frac{-1\,cm}{3\,cm}$$

$$= -0.33$$

Also,

$$M = -\frac{d_i}{d_o}$$



farther the image is from lens, the bigger it is

eg. from before

$d_o = 6 \quad d_i = 3$ $\quad M = -\frac{3}{6} = -\frac{1}{2}$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

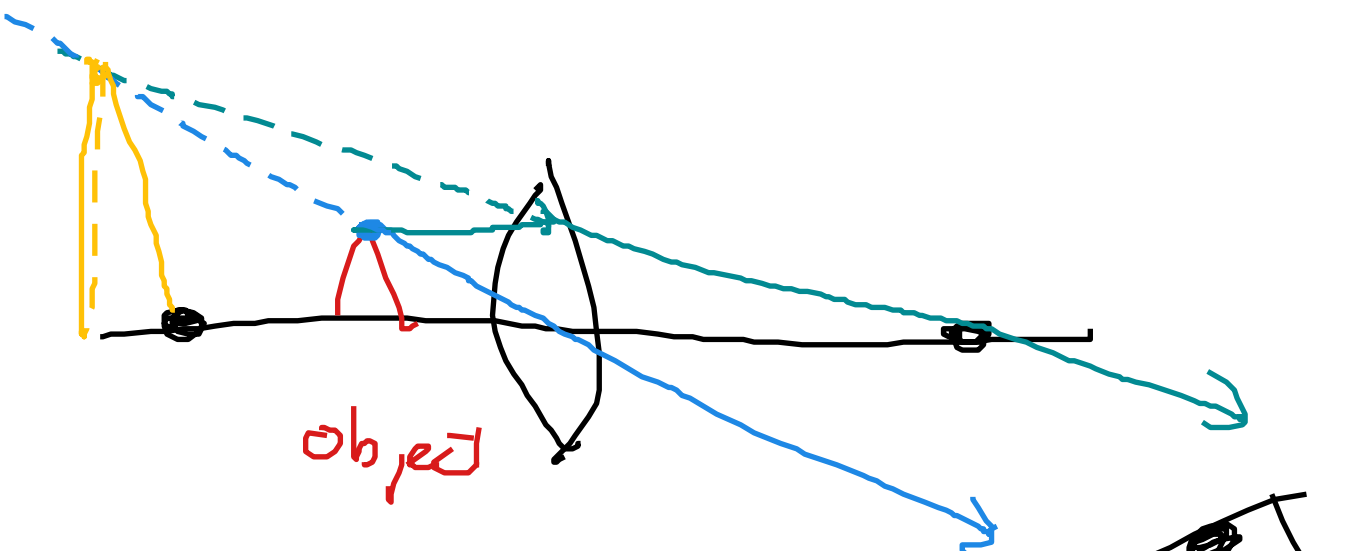
$$\frac{1}{d_i} = \frac{d_o}{d_o}\frac{1}{f} - \frac{1}{d_o}\frac{f}{f}$$

$$\frac{1}{d_i} = \frac{d_o - f}{f\, d_o}$$

$$d_i = \frac{d_o f}{d_o - f}$$

$$M = -\frac{d_i}{d_o} = -\frac{f}{d_o - f}$$

What if $d_o < f$?

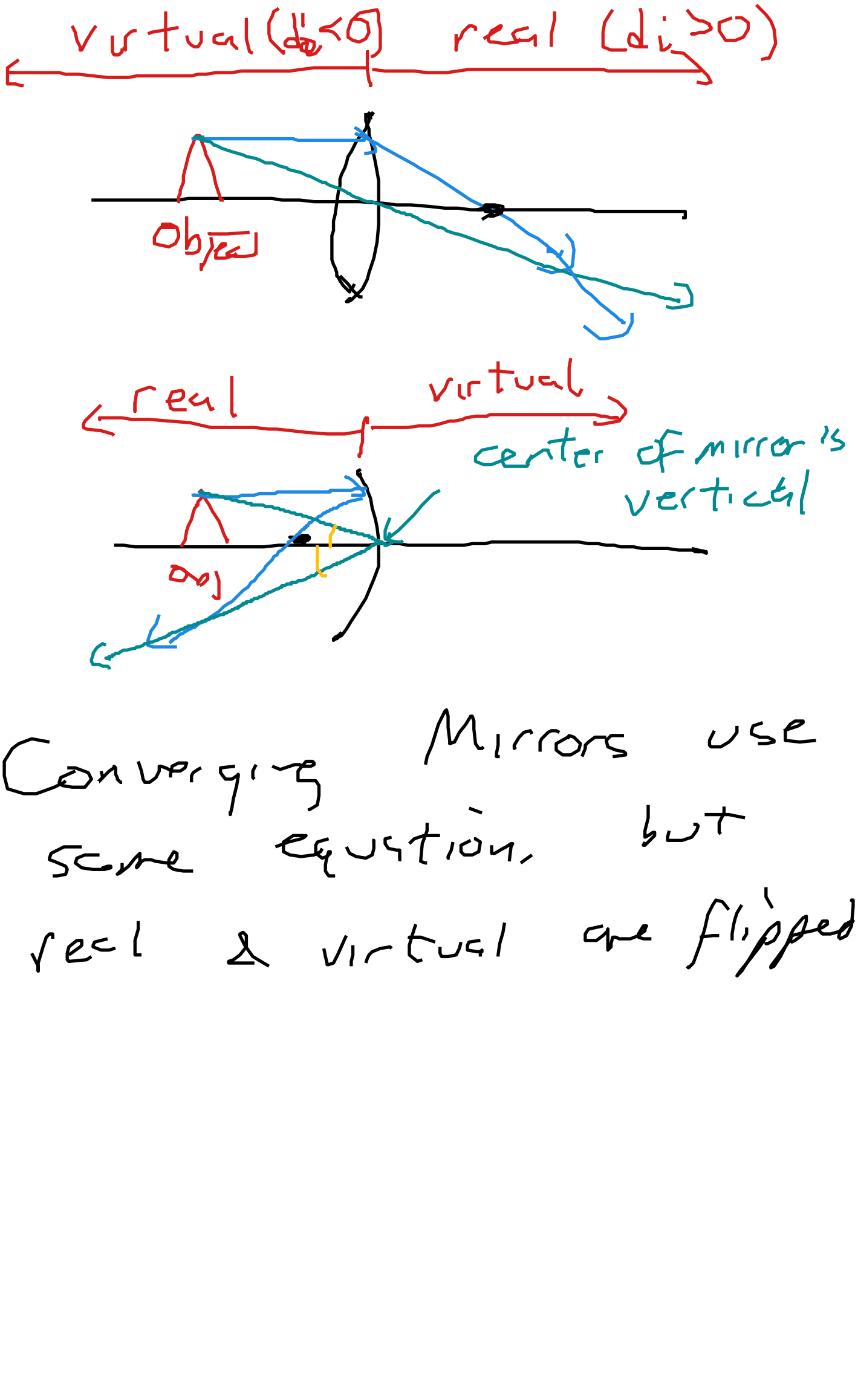


$$d_i = \frac{d_o f}{d_o - f} < 0$$

virtual image

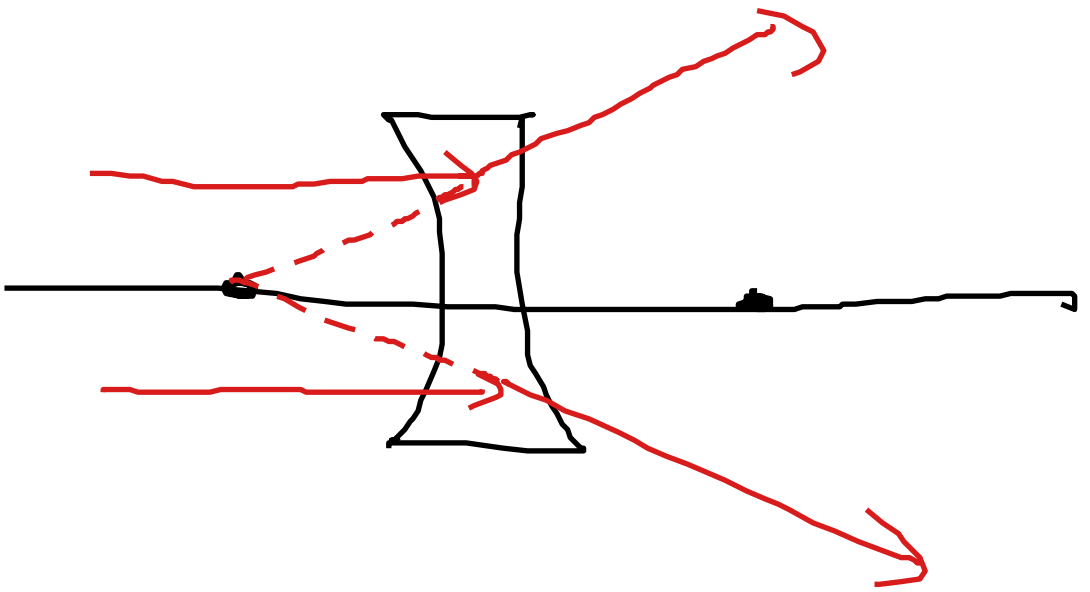
$d_i > 0$: real image

$d_i < 0$: virtual image



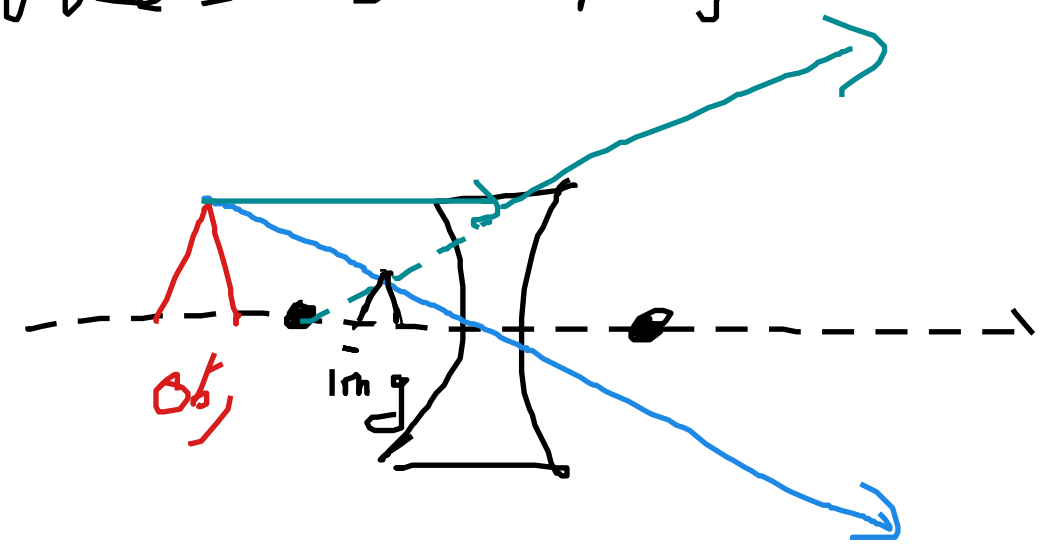
Converging Mirrors use same equation, but real & virtual are flipped

Diverging Devices



$f < 0$

focal length for diverging devices is negative



$$d_i = \frac{d_o f}{d_o - f} \qquad m = -\frac{f}{d_o - f}$$

$f = -5\,cm \qquad d_o = 8\,cm$

$$d_i = \frac{8(-5)}{8-(-5)} = -\frac{40}{13} \approx -3\,cm$$

virtual

$$M = -\frac{(-5)}{8-(-5)} = \frac{5}{13}$$

Diverging devices create smaller virtual images