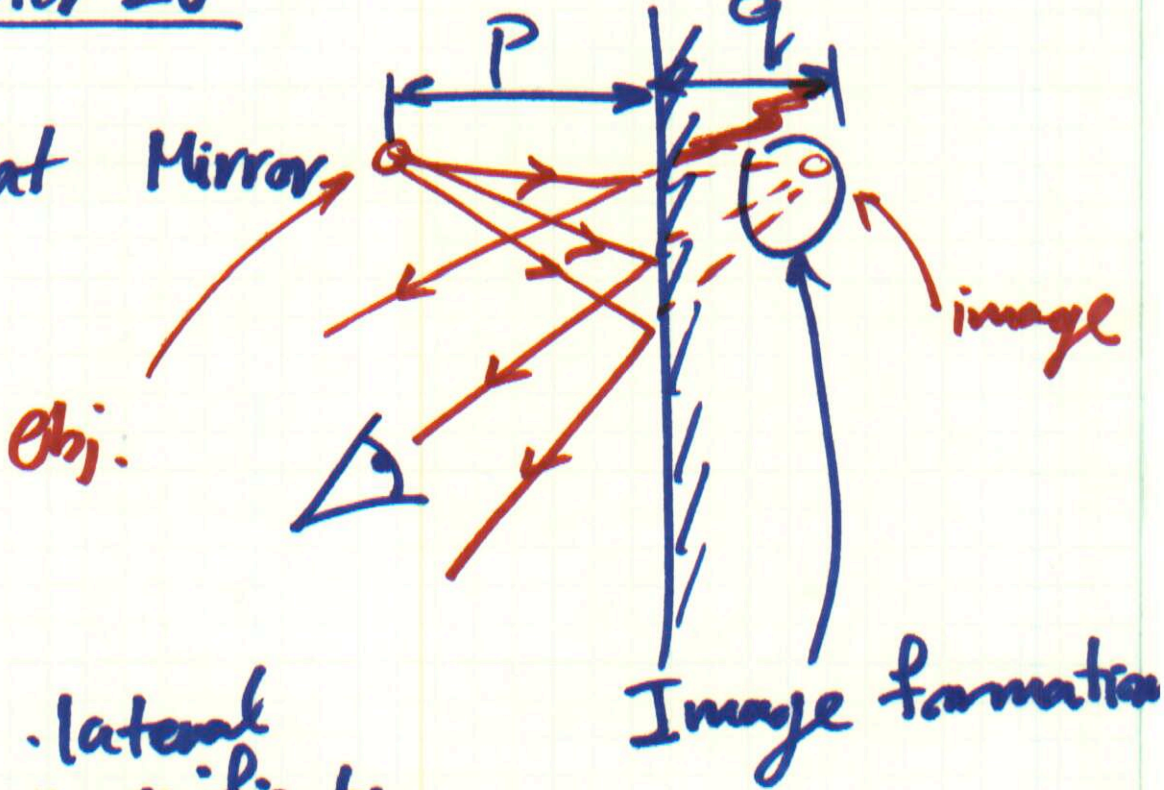
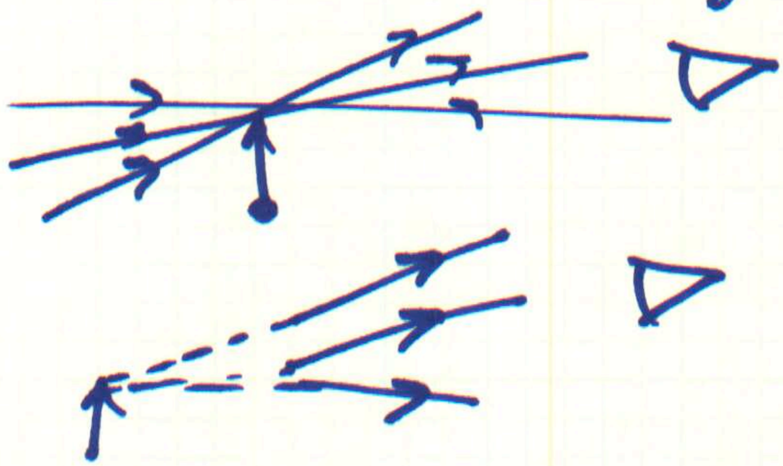
Chapter 26

Flat Mirror

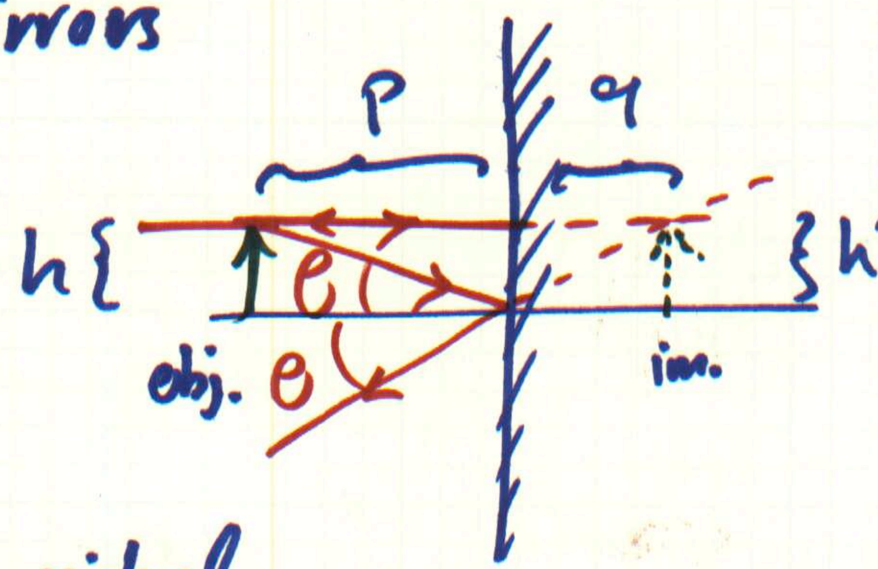


$M \equiv$ lateral magnification

Real vs. Virtual image



Flat Mirrors



-

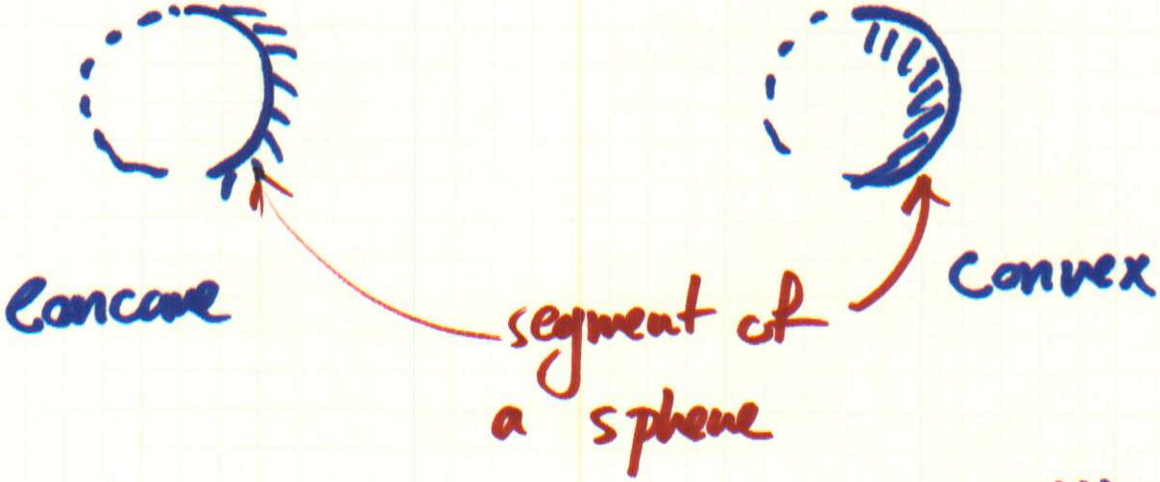
- Image is virtual
- 2 rays are needed to determine where an image is
- ~~right left reversal~~

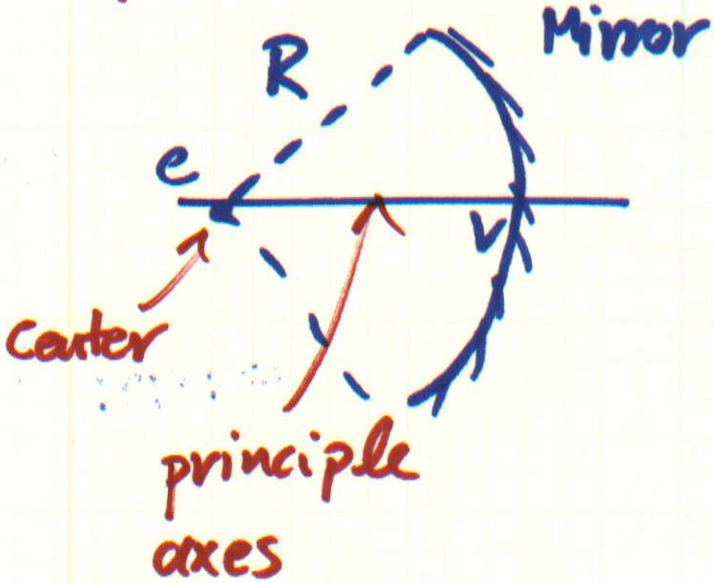
$p = |q|$

$M = \frac{h}{h'} = 1$

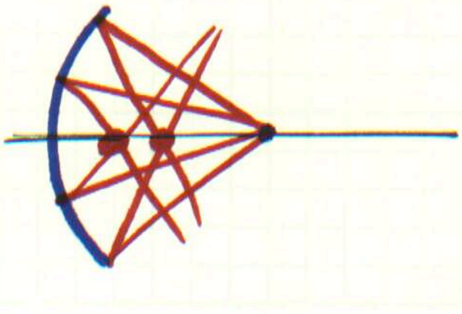
In general
- $M = 1$ im. looks the same as obj.
- $M > 1$ im. > obj.
- $M < 1$ im. < obj.

Spherical Mirrors



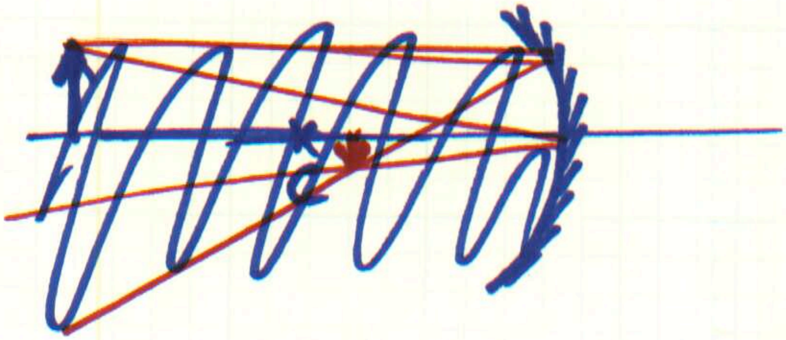


* Use only rays that make an small angle w/ the principle axes



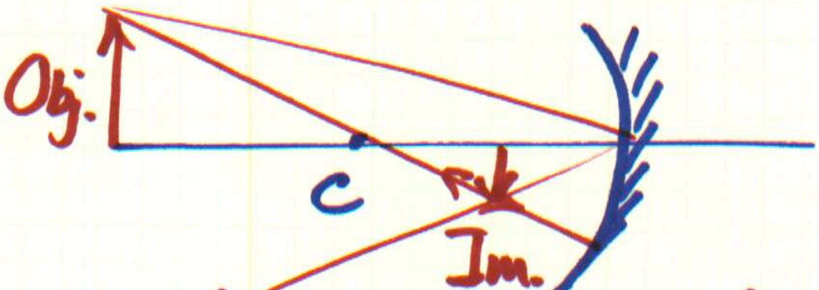
* Otherwise, rays converge to diff points
  ⇒ blurred im.
  ⇒ a.k.a <u>spherical aberra</u>

Concave Mirror



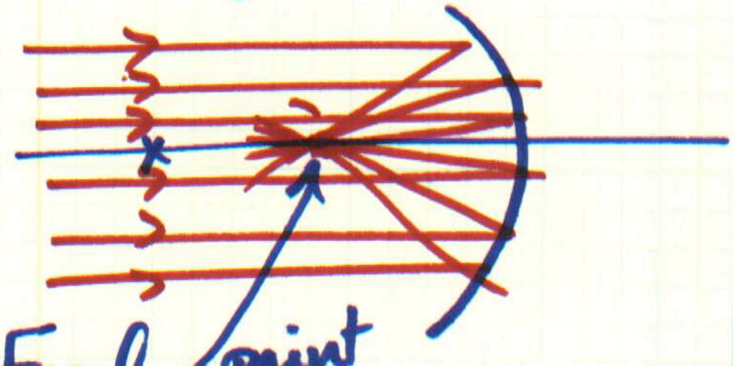
$$M = \frac{h'}{h} = -\frac{q}{p}$$

Also, $$\boxed{\frac{2}{R} = \frac{1}{p} + \frac{1}{q}}$$ Mirror equ.



If $p \gg R \longrightarrow \left(\frac{1}{p} \to 0\right)$ and $\left(q \approx \frac{R}{2}\right)$

Obj. far away (parallel rays)



$f \equiv$ dist. from mirror to the focal point

$f \approx \frac{1}{2} R$

$\Rightarrow$ f dep. on the curvature of the mirror only
[ind. of p & material]

$$\frac{1}{f} = \frac{2}{R}$$

$$\Rightarrow \boxed{\frac{1}{f} = \frac{1}{q} + \frac{1}{p}}$$

Convex Mirrors

a.k.a diverging mirrors

* rays diverge after reflection
* Img. is virtual

[rays "appear" to be originated at the im.]

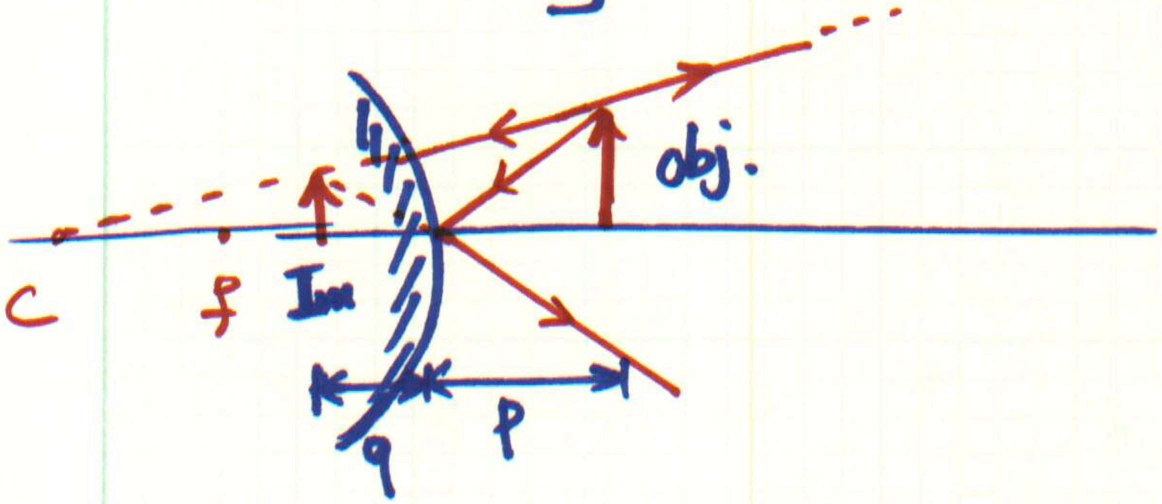


Image $\longrightarrow$ upright, virtual, smaller ($M<1$)

Signs

	+	−
P	in front (real)	in back (virtual)
q	infront (real)	in back (virtual)
h′	upright	inverted
f	concave (front)	convex (back)
R	〃	〃
M	Im. upright	Im. inverted

Ray Diagrams

We need: – p
– f

3 rays are need (all from the same point)

2 rays are suff.
an extra ray as a check

3 rays:

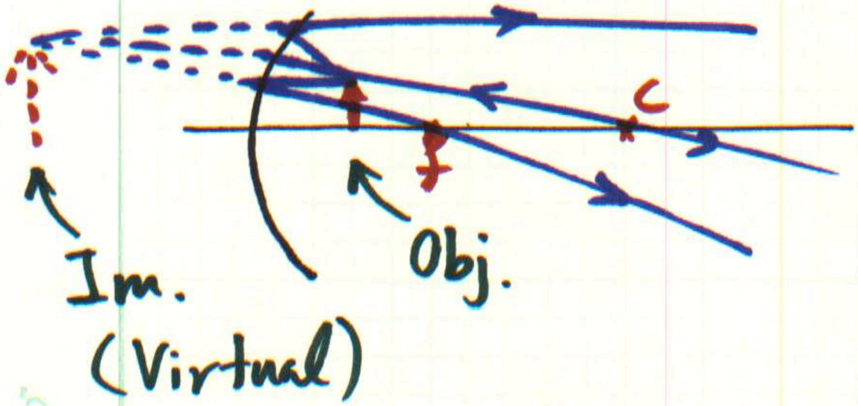
~~① parallel~~

① Parallel to principle axes
→ ref. through f.

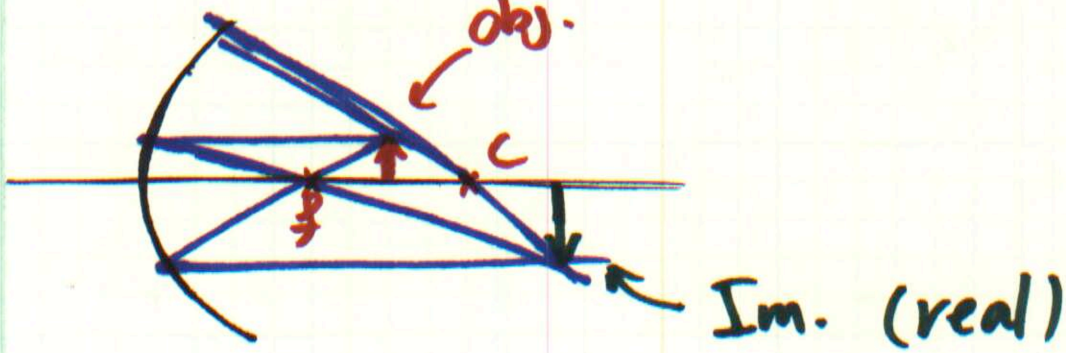
② Through f
→ ref. parallel

③ Through the center of curve. (C)
→ ref. back on itself

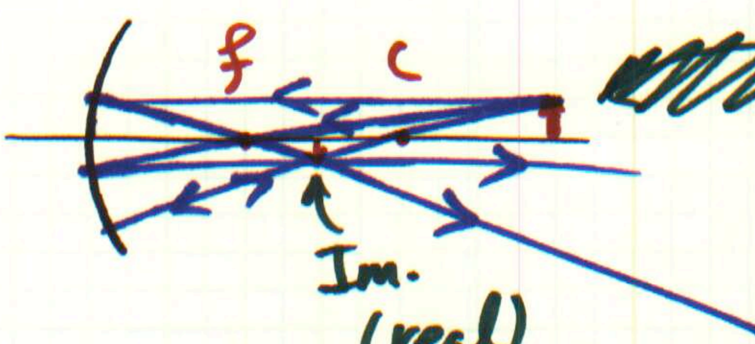
These are not the only rays
but 3 we usually use



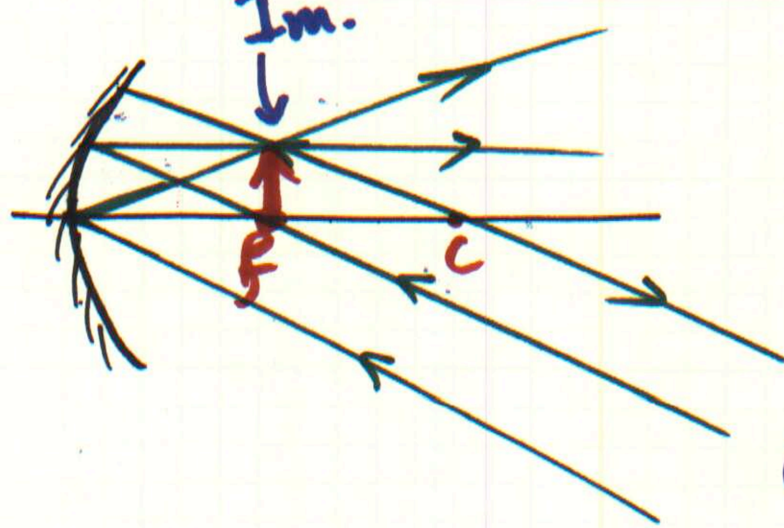
Im:
- ~~real~~ Virtual
- upright
- $|M| > 1$



Im:
- Real
- Inverted
- $|M| > 1$

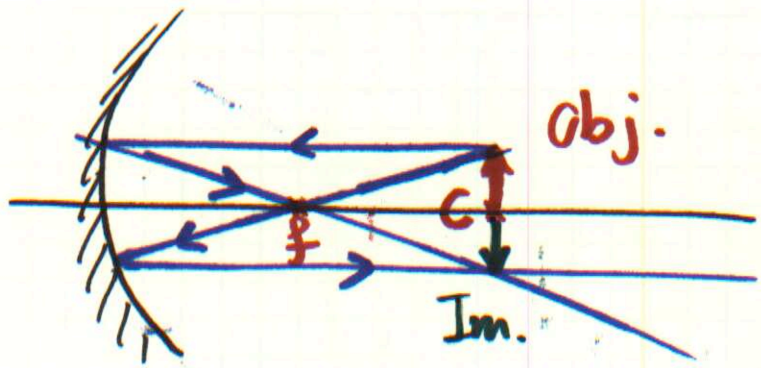


Im:
- Real
- Inverted
- $M < 1$

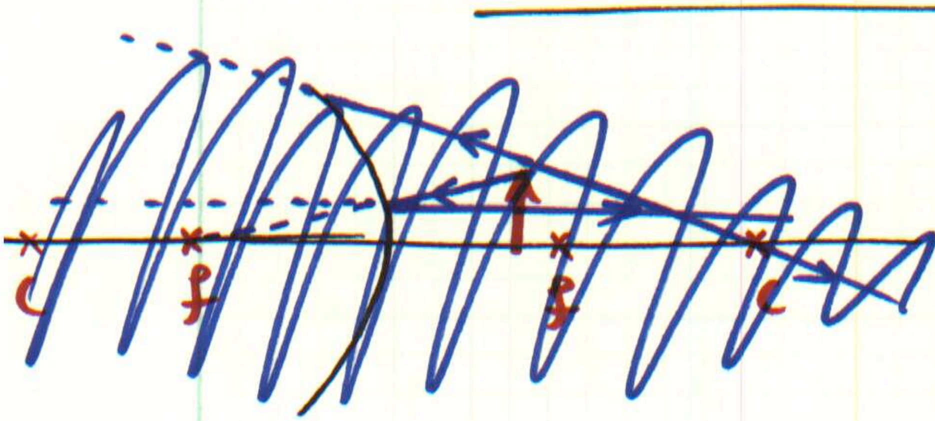


Im:
- Real
- Inv.
- $|M| < 1$

Obj. @ ∞



Im:
- Real
- Inv.
- $|M| = 1$



Canvex Mirror:

Im.:
- Virtual
- Upright
- $M<1$

Real Vs. Virtual

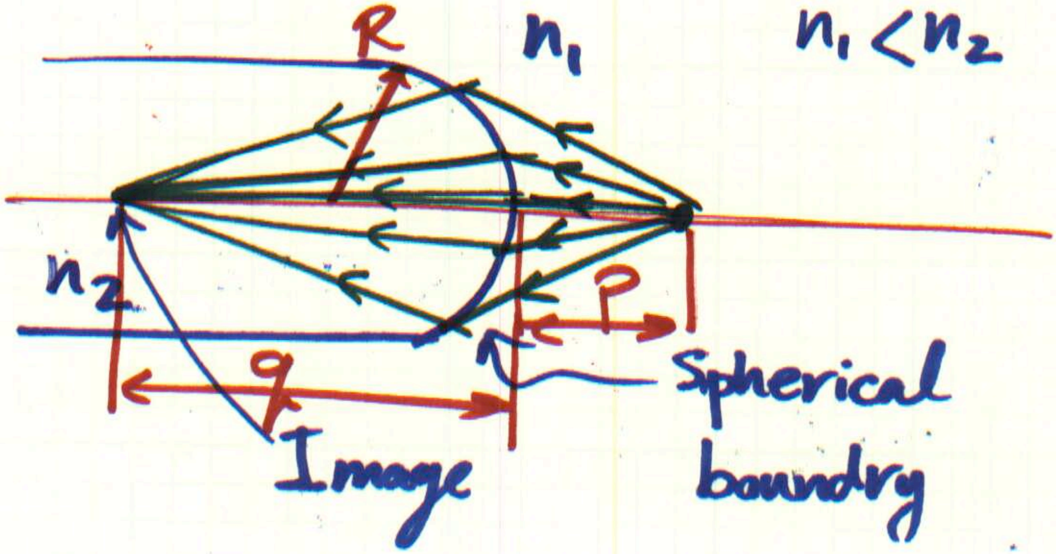
Real:

- ~~[illegible]~~
- Can be projected on a screen
- Made by real rays

Virtual:

- Cannot be proj. on a screen
- Made by cantinuatio of real rays

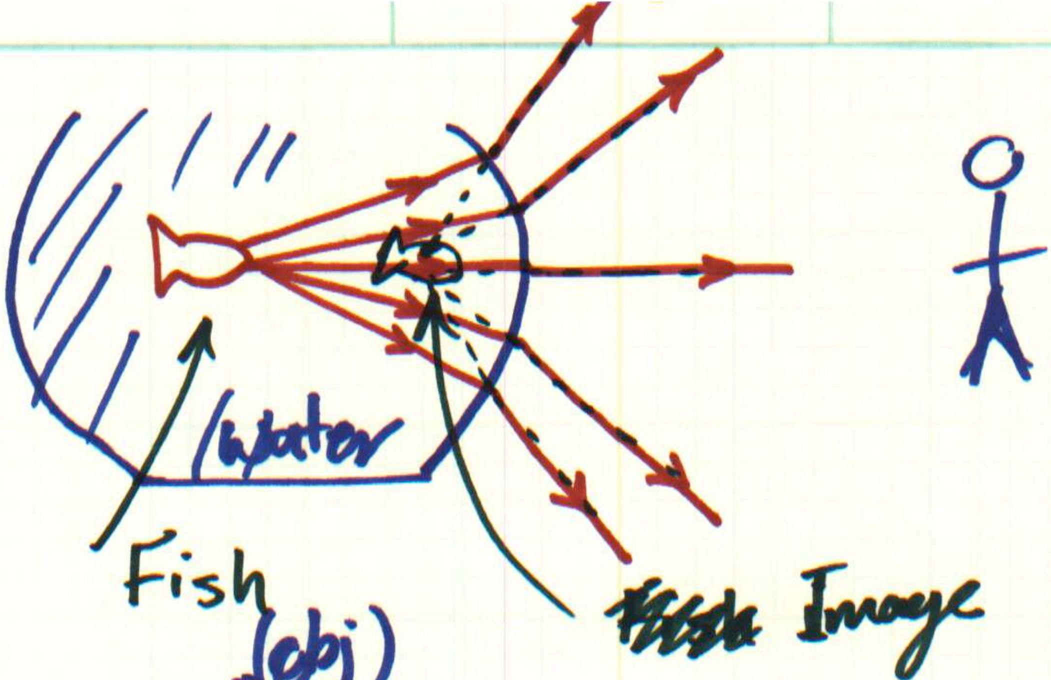
$n_1 < n_2$



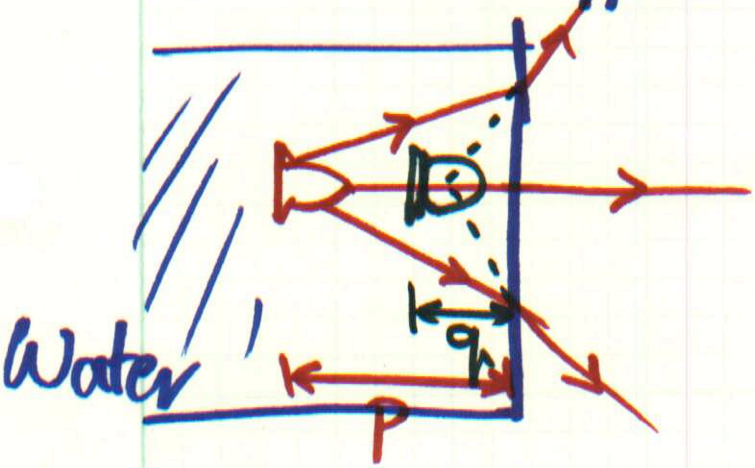
$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$$

Image ⟶ Real

	+	−
p	front	back
q	back	front
h′	upright	Inverted
R	center in the back	Center in the front



Fish (obj) appears to be closer



For a flat surf.:

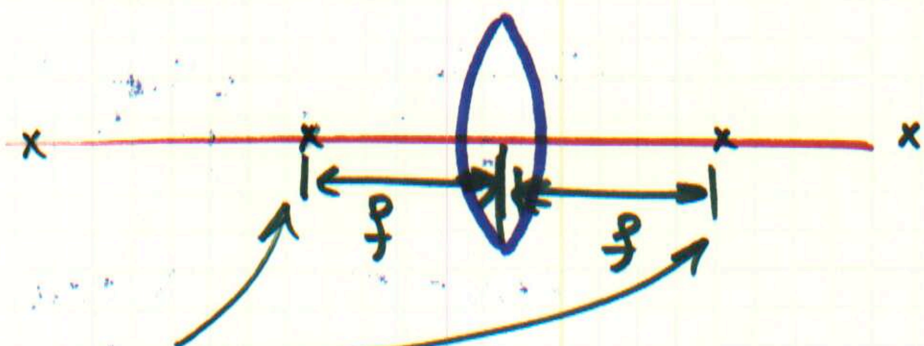
$$q = -\left(\frac{n_2}{n_1}\right)p$$

In both cases the image is virtual

Lenses

Used in cameras, telescopes, Microscopes, ...

Assumption: thickness of lens is small



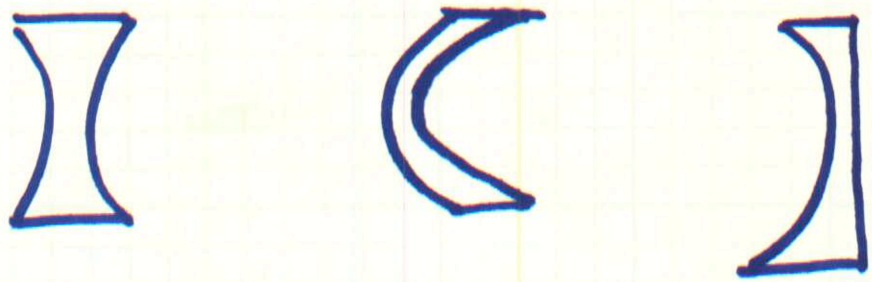
two focal points

Converging lenses:

$f \rightarrow +$

thick in the middle

Diverging lenses



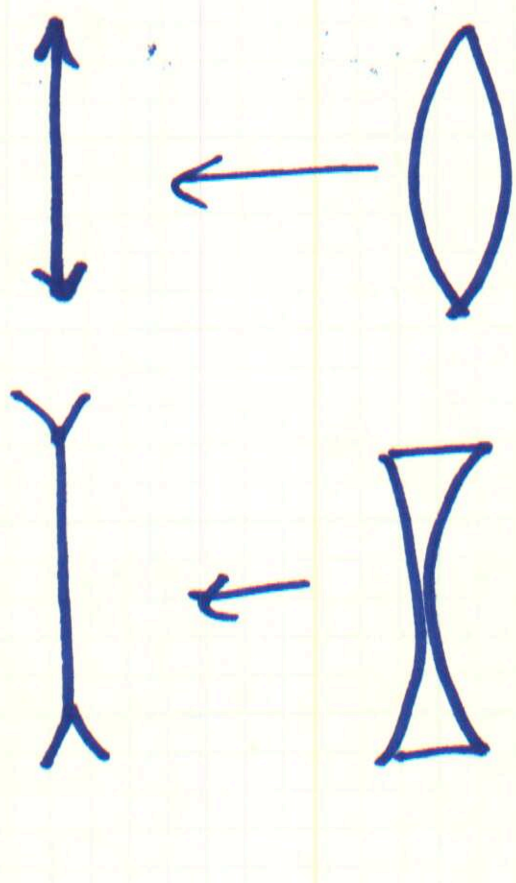
Bicancave

Convex-Concave

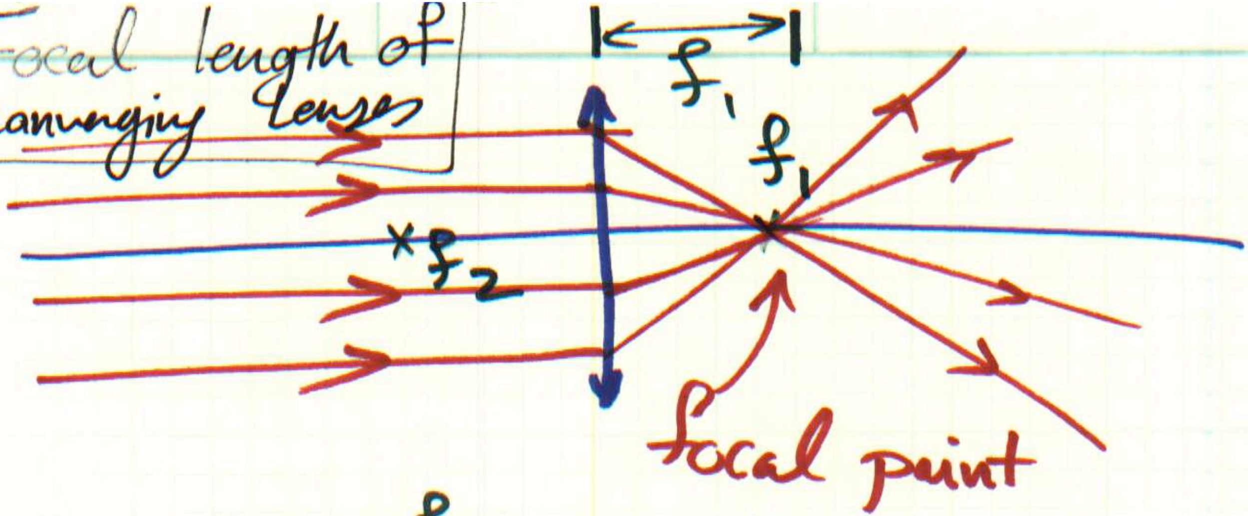
Plano-concave

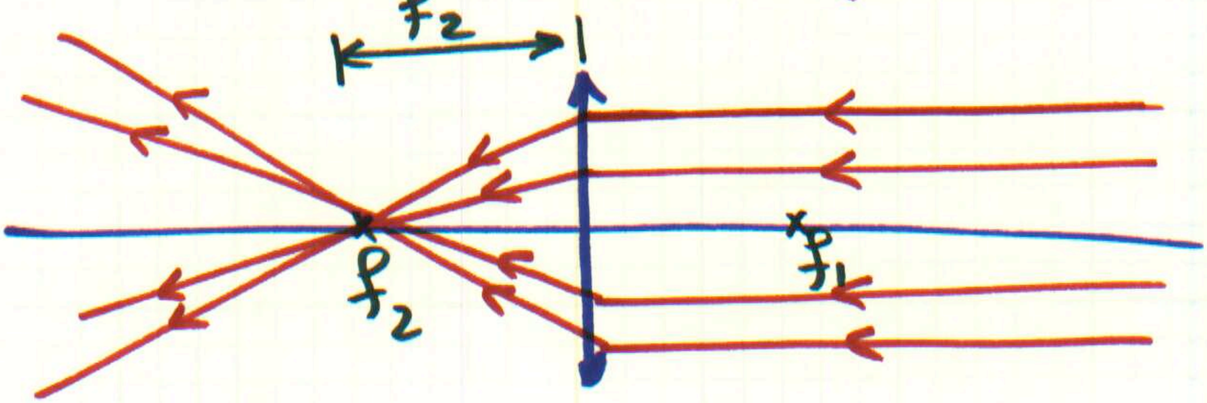
$f \rightarrow -$

thin in the middle



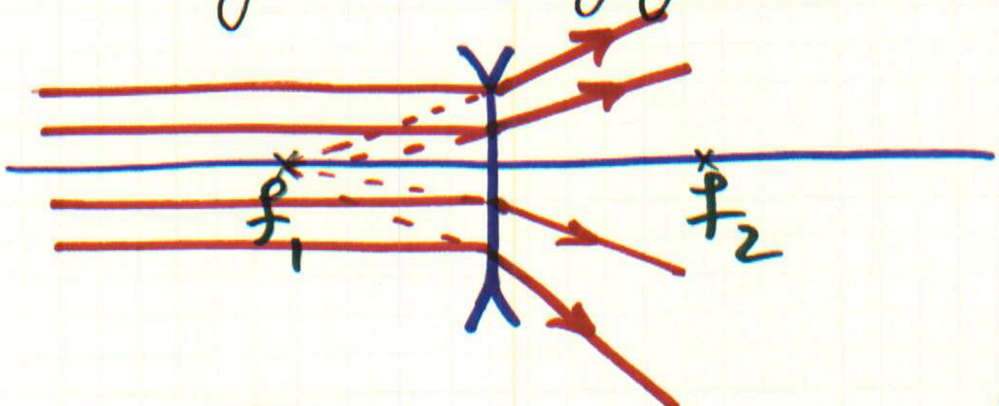
Focal length of converging lenses



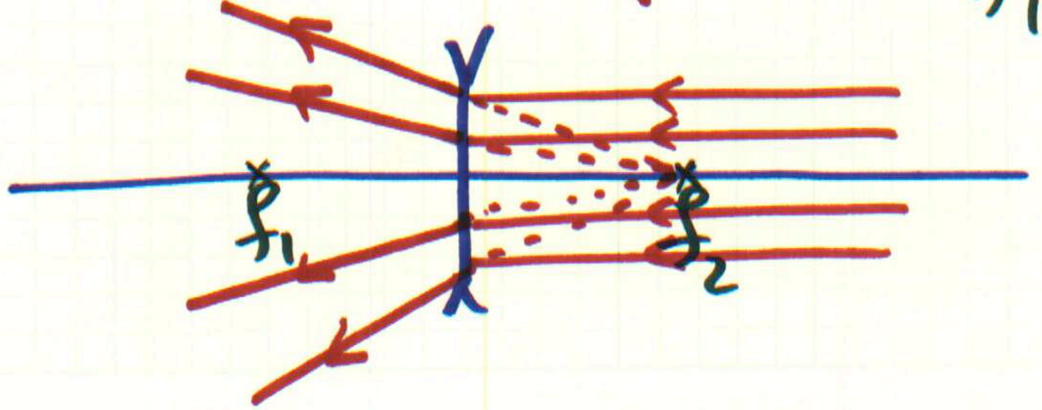


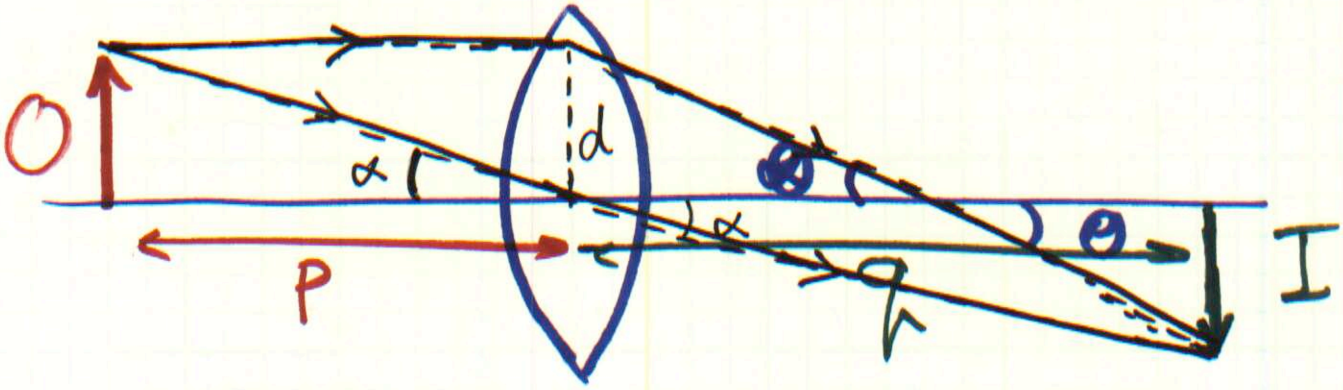
$f_2 = f_1$

Focal Length of Diverging Lenses



$f_1 = f_2$





$$\begin{cases} \tan\alpha = \dfrac{h}{p} \\[2ex] \tan\alpha = -\dfrac{h'}{q} \end{cases} \qquad \begin{cases} \tan\theta = \dfrac{d}{f} \\[2ex] \tan\theta = -\dfrac{h'}{q-f} \end{cases}$$

$$\boxed{M = \frac{h'}{h} = \frac{-q}{p}}$$

$$d = h \implies \frac{h}{f} = -\frac{h'}{q-f}$$

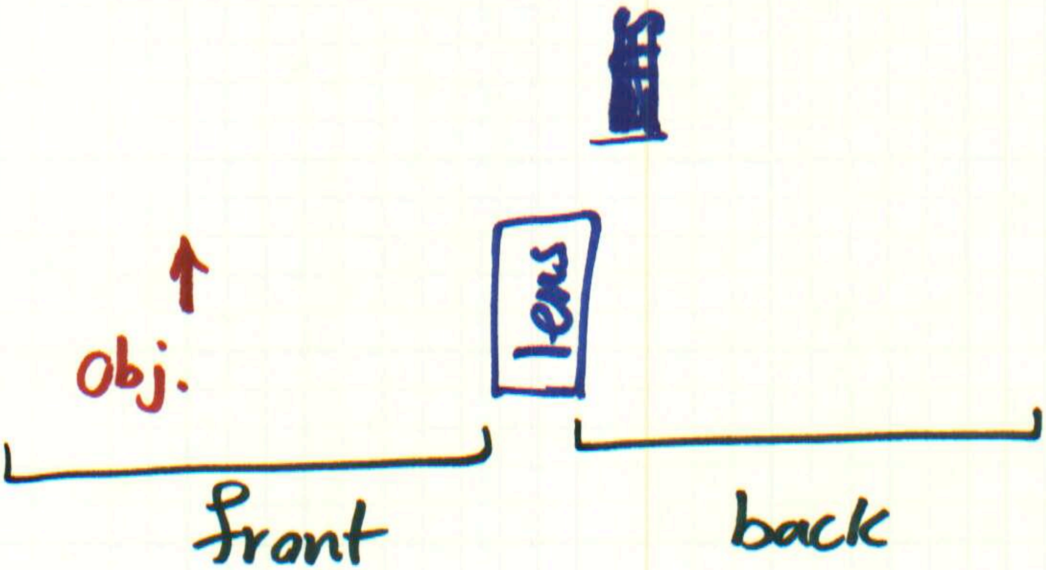
$$\downarrow$$

$$\frac{h}{h'} = -\frac{f}{q-f}$$

$$\downarrow$$

$$\frac{p}{q} = -\frac{f}{q-f}$$

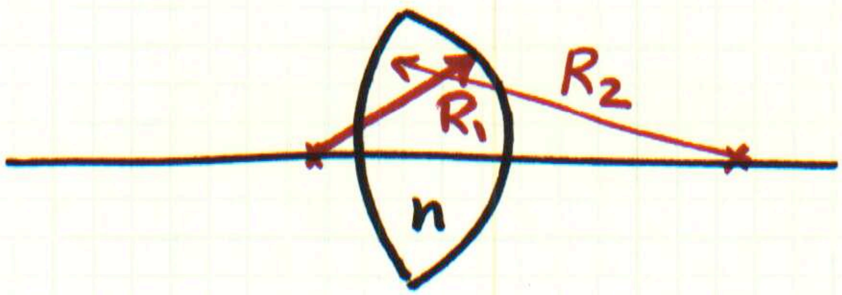
$$\implies \boxed{\frac{1}{f} = \frac{1}{q} + \frac{1}{p}}$$ Lens eqn.



	+	−
P	front	back
q	back	front
h'	Upright	Inverted
f	conv. lens	Div. lens
R_1/R_2	c in back	c in front

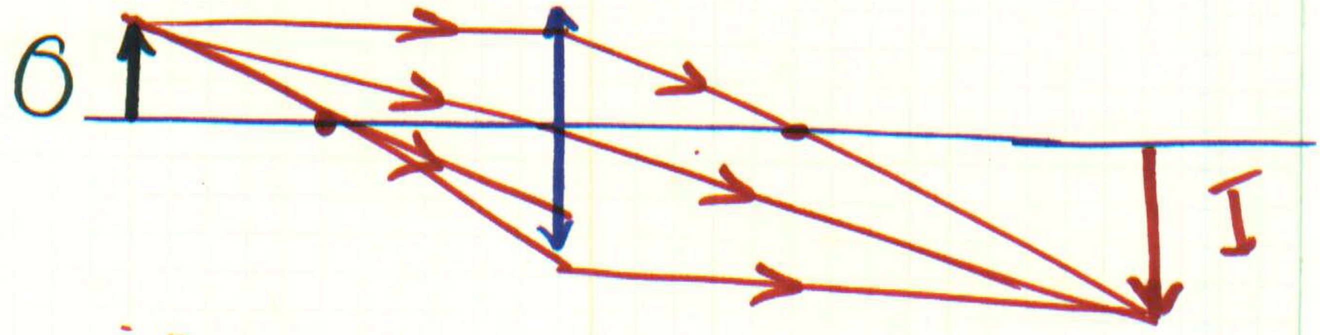
Lens Makers Eqn.

$$\boxed{\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

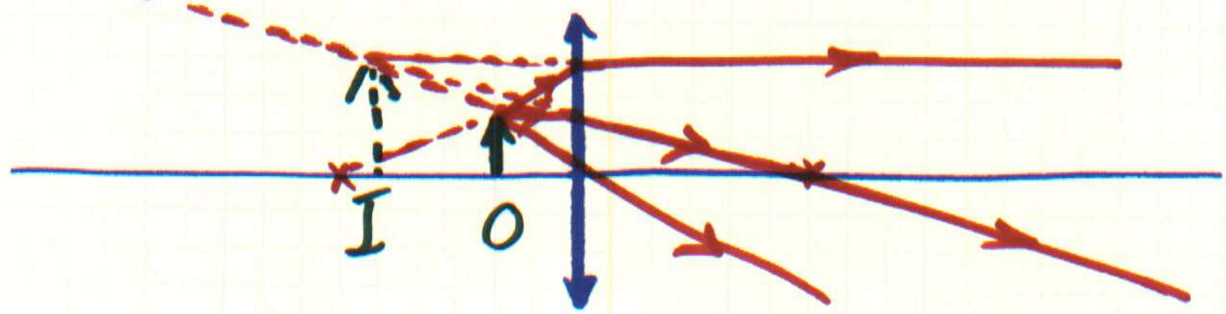


f only depends on $\underline{n}$ & the curvature of the lens

1



2



1 Image: - real
- inverted $M<0$
- behind the lens ~~q~~ $q>0$

Image: - Virtual
- Upright $M>0$
- In front of the lens $q<0$

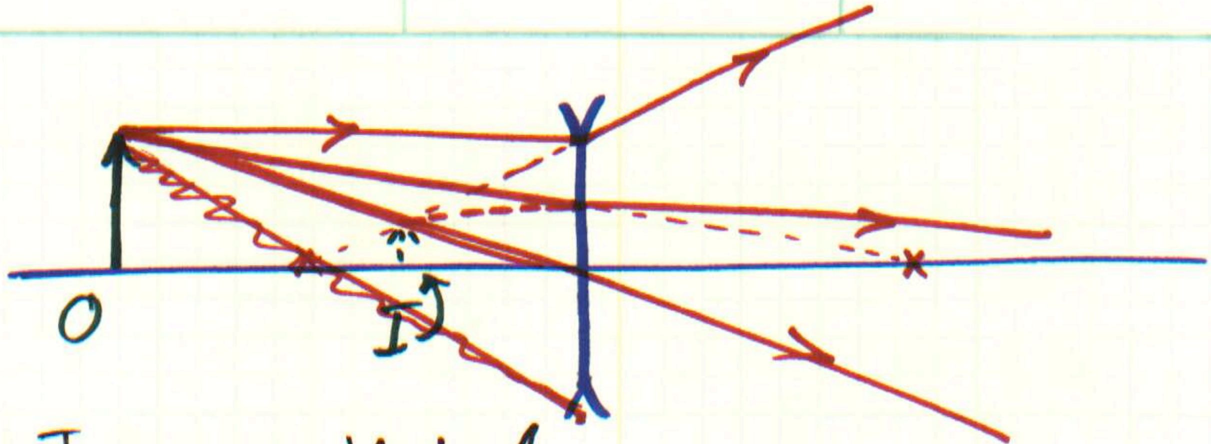
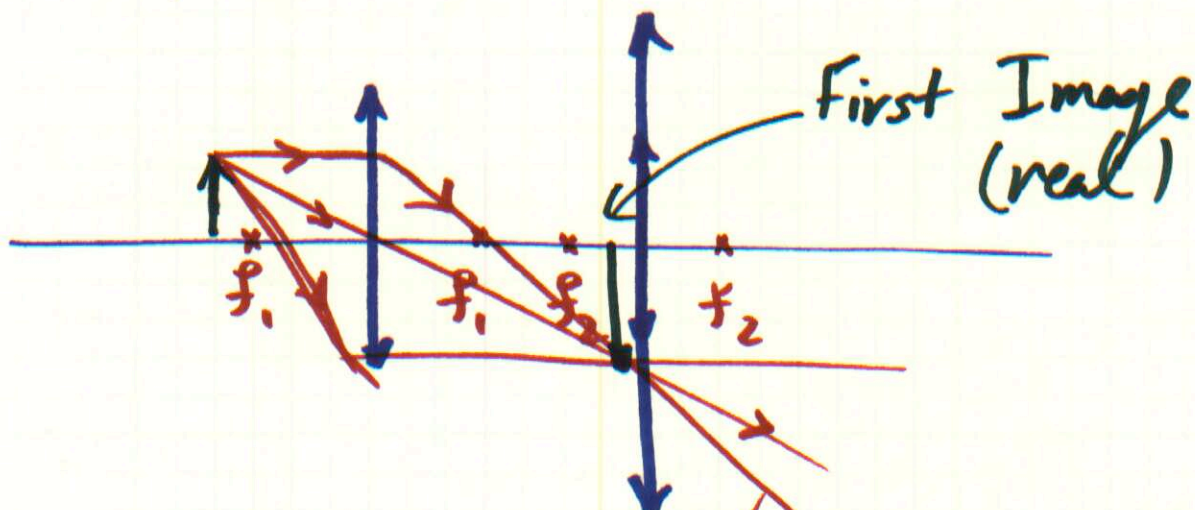
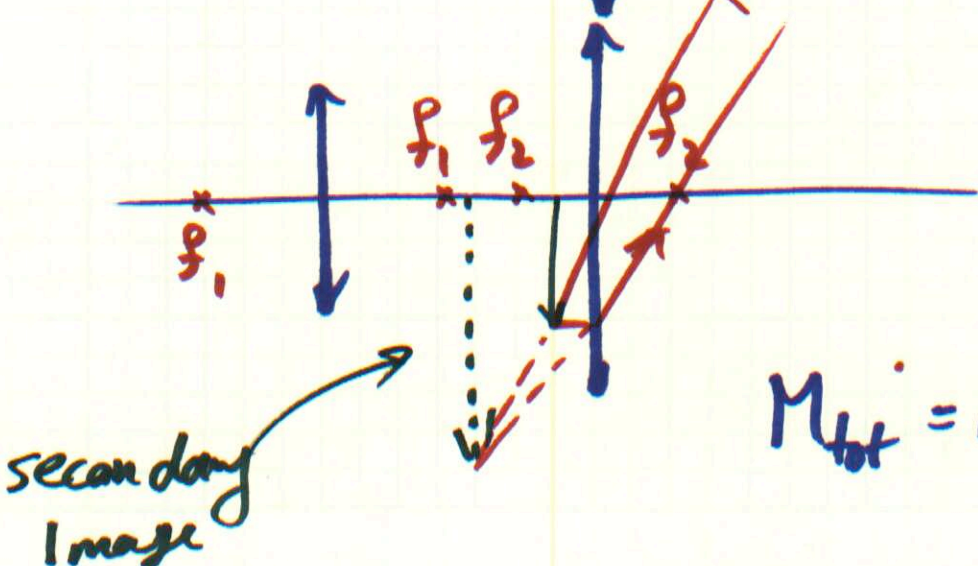


Image: - Virtual
- ~~tave~~ Upright $M>0$
- in the ~~back~~ front $q<0$
- $M<1$

<u>Multiple Lenses</u>





$$M_{tot} = M_1 \cdot M_2$$