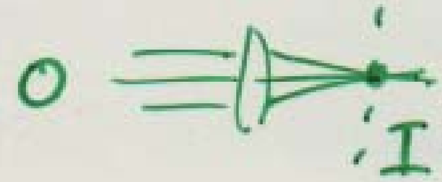
Chapter 24 Reading Quiz

1. Which is a true statement? A real image

x a) is always smaller than the object

(b) can be projected onto a screen



x c) is formed by a concave (diverging) lens

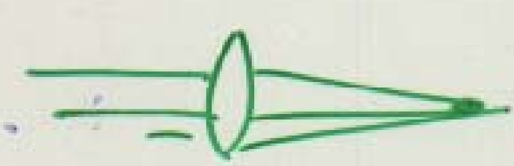
x d) is formed on the same side of a lens as the object

2. When a glass ($n = 1.5$) converging lens is immersed in water ($n = 1.33$), its focal length

(a) increases

b) decreases

c) stays the same



$n = 1.33$

d) not enough info.

3 Light enters a plano-convex lens:  from the left. When this thin lens is flipped around  the focal length:

a) decreases

b) stays the same

c) increases

d) changes sign (positive → negative)

4. A convex mirror produces images....

✓ a)... like a concave lens

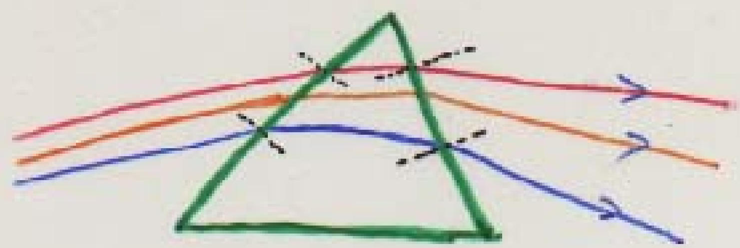
✗ b)... that are magnified

✗ c).... that are real

✗ d)...that are inverted (upside-down).

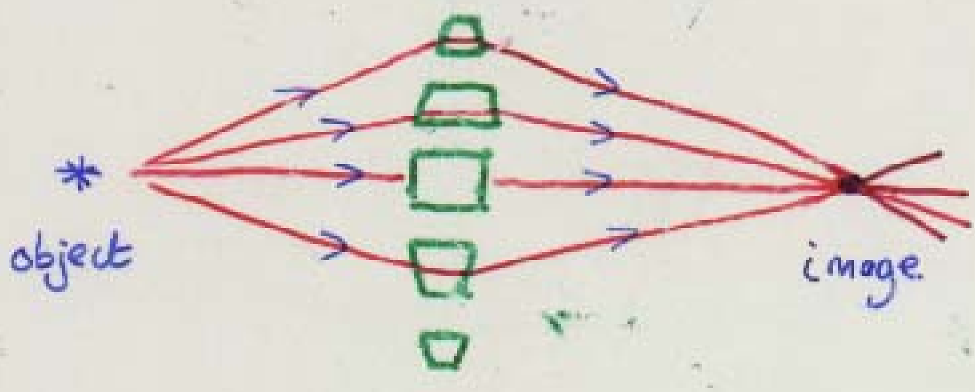
Prisms and Lenses

"Prism" - any block of glass with non-∥ faces bends light (Use Snell's Law at each surface).



Here, since n changes with freq. ⇒ dispersion

We can cleverly arrange prisms to collect light from a point source and bend rays to a common point → image formation



If point object → point image we have a <u>lens</u>

Spherical Thin Lenses

If lens surfaces are sections of spheres (easy to make) **AND** light from object is close to symmetry axis ("paraxial rays")

$\Rightarrow$ sharp images formed.

S_0: object distance (place object on left)

S_i: image distance

R_1, R_2: left, right radii of sphere

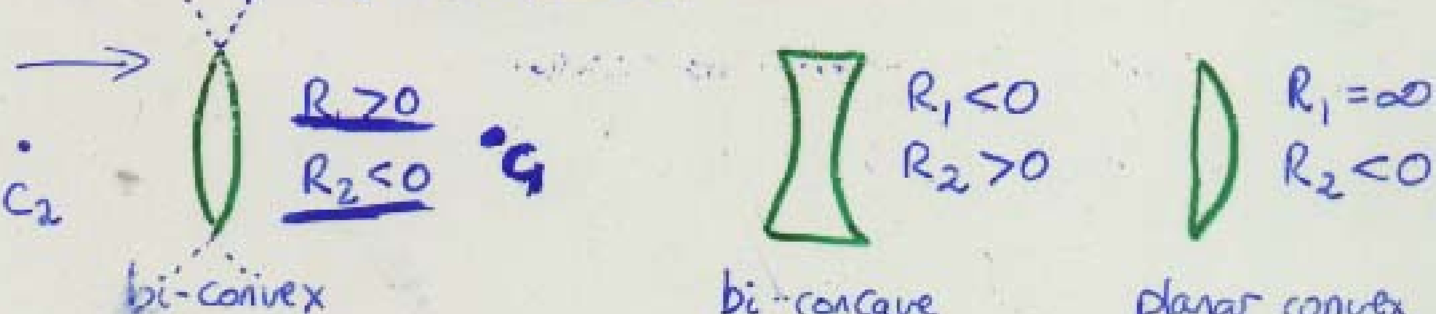
>0 if center on right (lens "bulges" to left)

Laws of Refraction

$$\Rightarrow \quad \frac{1}{S_0} + \frac{1}{S_i} = \left(\frac{n_g}{n_a} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

– Thin Lens Equation

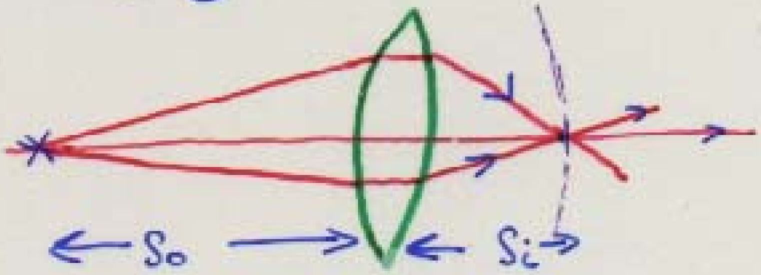
See Hecht fig. 24.7:



bi-convex bi-concave planar convex

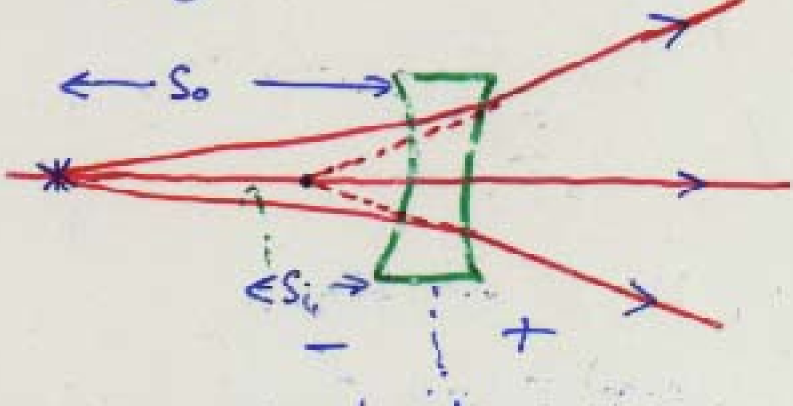
Lens and Image Types

1. Converging:



- forms image on right where rays converge so can be focussed onto screen: "real" image with $S_i > 0$.

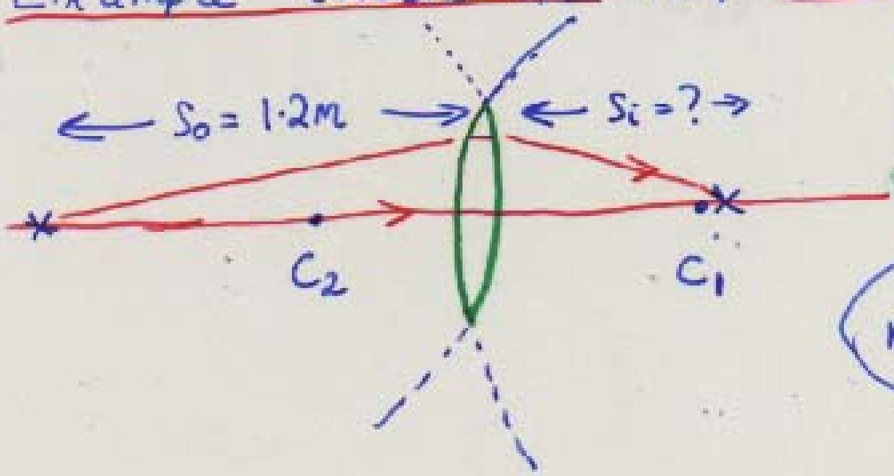
2. Diverging:



Here, rays appear to diverge from image behind lens ($S_i < 0$): "virtual" image

(c.f. plane mirror)

Example (Hecht ex 24.1 : Biconvex lens



$R_1 = 60cm$
$R_2 = -30cm$

$n = 1.5$

Since 2nd face has center of curvature on left $R_2 < 0$.

Given object distance $S_o = 120cm$, what is S_i ?

Use $$\frac{1}{S_o} + \frac{1}{S_i} = \left(\frac{n}{1.0} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{S_i} = (1.50 - 1)\left(\frac{1}{0.6m} - \frac{1}{-0.3m}\right) - \frac{1}{1.2m}$$

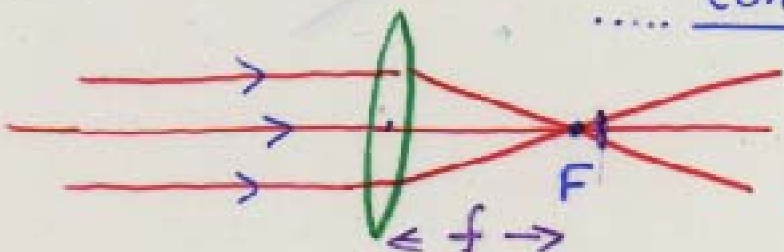
$$\Rightarrow S_i = +0.6m = +60cm$$

- $S_i > 0$ means image is formed on the right i.e. a real image
- Setting $R_1 = -60cm$, $R_2 = +30cm$ flips lens left-right $\Rightarrow$ same result for S_i

Focal Point of Lenses

Define focal point where rays and close to optical axis either....

..... converge :

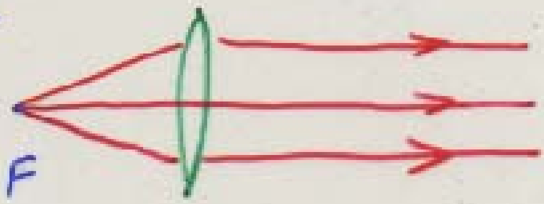


$S_o = \infty$

$\Rightarrow S_i = f > 0$

↳ focal length.

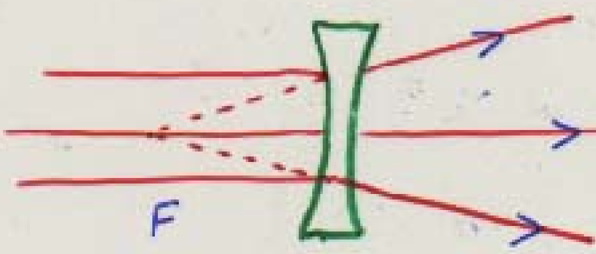
or in reverse



$S_o = f$

$\Rightarrow S_i = \infty$

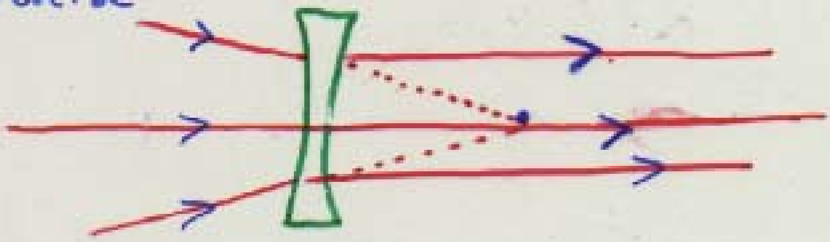
.... or appear to diverge :



$S_o = \infty$

$\Rightarrow S_i = f < 0$

or in reverse



$S_o = -f$

$\Rightarrow S_i = \infty$

From Thin Lens equation:

$$\frac{1}{S_o} + \frac{1}{S_i} = \underbrace{\left(\frac{n_g}{n_a} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}_{1/f}$$

setting $S_o = \infty$ for incoming ~~//~~ light,

we find $\frac{1}{f} = \left(\frac{n_g}{n_a} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Converging lens $\Rightarrow$ focal length $f > 0$ ("positive lens")

diverging " $\Rightarrow$ $f < 0$ ("negative lens")

So $\boxed{\frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{f}}$: Gaussian Lens Equation

i.e. given focal length f and object distance S_o, can find image distance S_i

e.g. for Hecht example ~~23~~ 24-1, $R_1 = 60\text{cm}$, $R_2 = -30\text{cm}$

$$\Rightarrow \frac{1}{f} = (1 \cdot 5 - 1)\left(\frac{1}{60} - \frac{1}{-30}\right) \Rightarrow f = +40\text{cm}$$

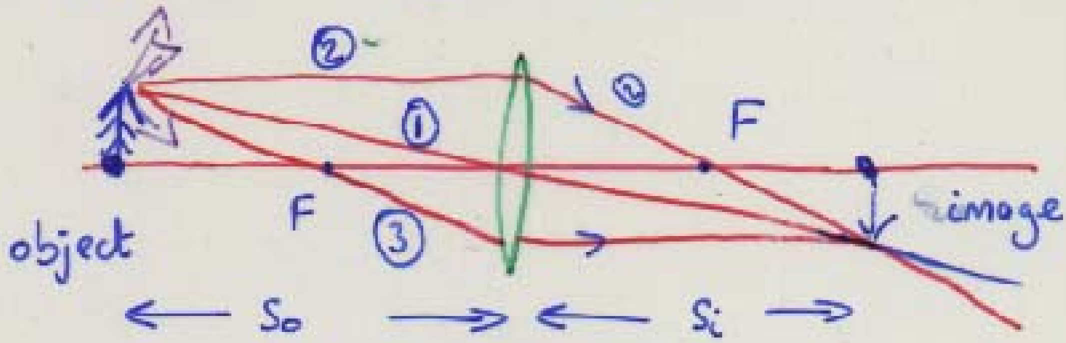
So with $S_o = +60\text{cm}$

$$\frac{1}{S_i} = \frac{1}{40} - \frac{1}{60} \Rightarrow S_i = +120\text{cm} \text{ as before.}$$

Ray Diagrams

Can use geometry to construct images by tracing 2 or 3 rays through lens

e.g.



Ray ① passes through optical center of lens

Ray ② ∥ to optical axis, passes through focus F

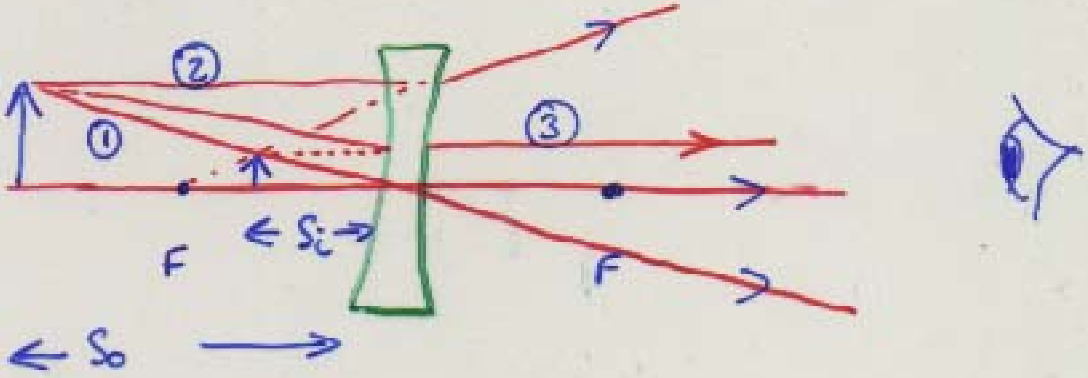
Ray ③ through near-side focus, emerges ∥ to optical axis.

⇒ image is : real (rays converge)

inverted

"minified" (smaller than object)

Diverging Lens



Resulting image is : <u>virtual</u> (behind lens, rays appear to diverge)
erect
minified

Note: Converging lens can also produce virtual image: (when object inside focal length, $s_o < f$)

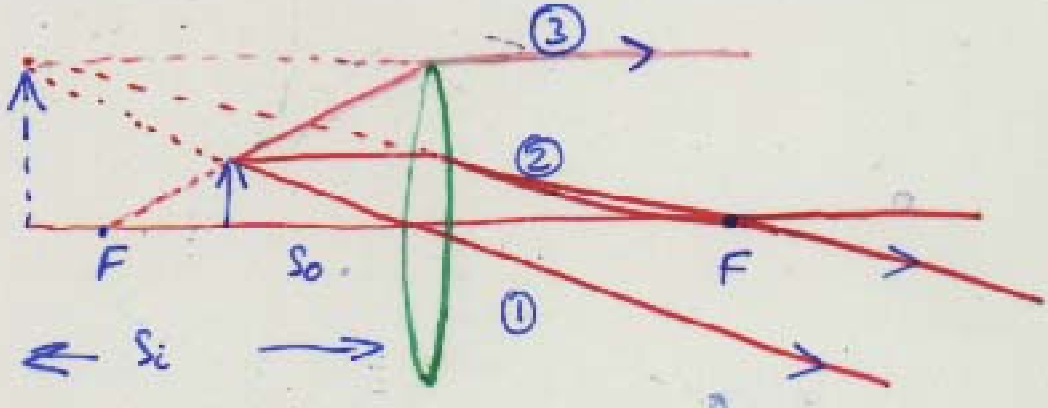


image is virtual, erect, <u>Magnified</u>

(magnifying glass)