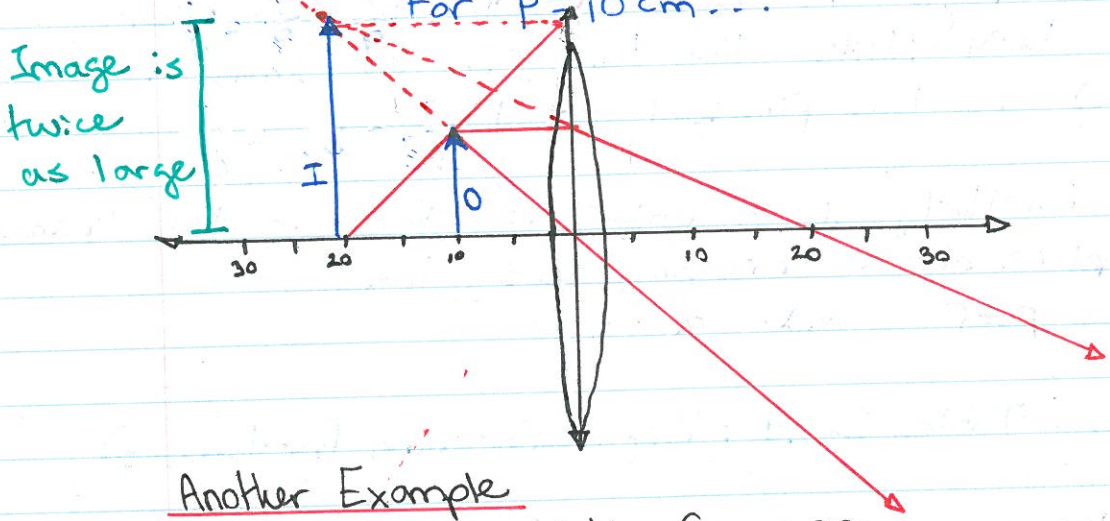
Lecture 13

Thursday Feb 25th, 2016

Example continued from last class...

b) Converging lens, $f = 20\,cm$

For $p = 10\,cm$...



Another Example

Diverging lens with $f = -20cm$:

a) $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

$\frac{1}{q} = \frac{1}{F} - \frac{1}{p}$

$= \frac{1}{-20} - \frac{1}{30}$

$= -\frac{5}{60}$

$= -12\,cm$

- $q = -12\,cm$
- Virtual (since q is negative)
- $m = 0.40$
- Upright

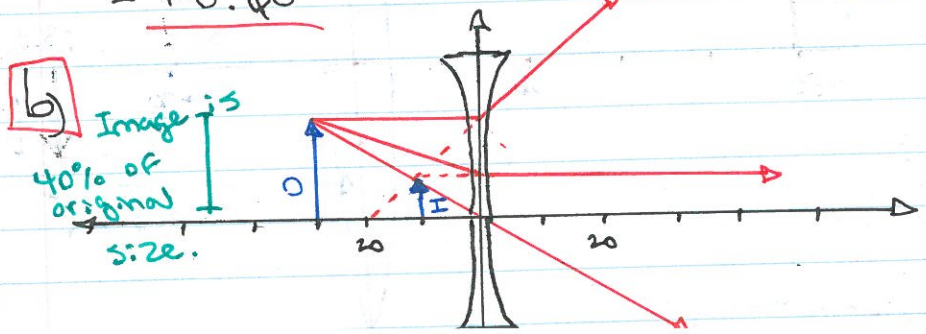
$m = -\frac{(-12)}{30}$

$= +0.40$

For the other values...

p	q	Real/Virtual	m	↑ or ↓
30	-12	Virtual	0.4	Upright
20	-10	Virtual	0.5	Upright
10	-6.67	Virtual	0.67	Upright

b)



24.1 Lenses in Combination

Consider a 2 lens system. The object distance (p) is the distance from the image formed by the first lens to the second lens

This makes it possible to have a virtual object. where the p value is negative.

Real Object: rays diverge from a point on the object and enter the lens on the left side.

Virtual Object: rays enter the lens as if they are converging towards the object which is on the right side. (see slides for illustrations from the text).

*If lens 1 forms a real image past lens 2, the image is virtual for lens 2.
If lens 1 forms a real or virtual image before lens 2, the image is real for lens 2.

The object distance p_2 for the second lens is:

$$p_2 = s - q_1$$

Always gives the right sign for p_2

Ray Diagrams for 2 Lenses.

In a two lense system, only one of the principal rays for lense 1 is a principal ray for the second lens.

Note: There is no rule allowing Ray 2 to be drawn for lens 2 without already knowing the final image.

Transverse Magnification

Suppose N lenses are used in combination.

h = the size of the object

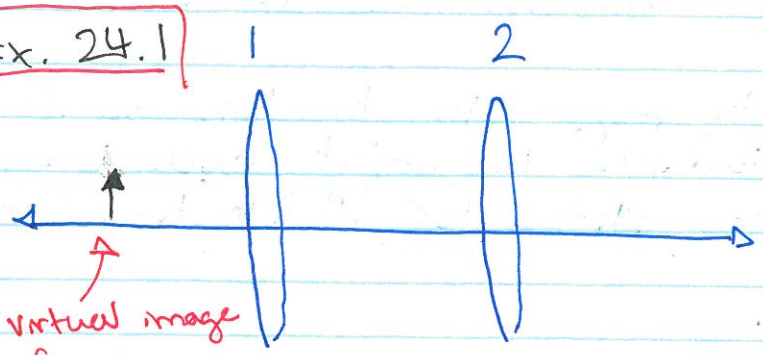
h_1 = the size of the image formed

$$\frac{h_N}{h} = \frac{h_1}{h} \times \frac{h_2}{h_1} \times \frac{h_3}{h_2} \times \dots \times \frac{h_N}{h_{N-1}}$$

The total transverse magnification due to the N lenses is the product of the magnifications due to the individual lenses.

$$m_{total} = m_1 \times m_2 \times \dots \times m_N$$

Ex. 24.1



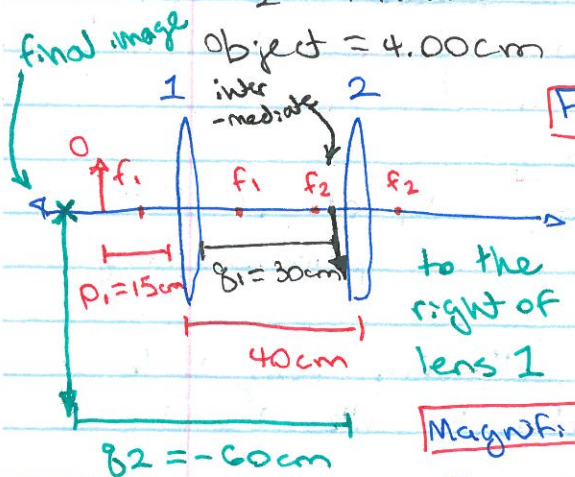
for lens 1, and so if it is to the left of lens 2, then it is a real image for lens 2.

Ex. 24.2 Two converging lenses. distance = 40cm

$f_1 = +10.0\,cm$

$f_2 = +12.0\,cm$

Object = 4.00cm placed 15 cm in front of lens 1.



For lens 1,

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

$$\frac{1}{q_1} = \frac{1}{f_1} - \frac{1}{p_1}$$

$q_1 = 30cm$ to the right of lens 1

For lens 2,

$p_2 = 40 - 30 = 10\,cm$ ← new object for lens 2

$$\frac{1}{q_2} = \frac{1}{f_2} - \frac{1}{p_2}$$

$$= \frac{1}{12\,cm} - \frac{1}{10\,cm}$$

$$= -60cm$$

Magnification:

$$m = m_1 m_2$$

$$= \left(-\frac{q_1}{p_1}\right)\left(-\frac{q_2}{p_2}\right) = (-2)(6)$$

$$= \left(-\frac{30}{\quad}\right)\left(-\frac{(-60)}{\quad}\right) = -12$$

The final image height

is $h_{final} = m \times h_{object}$ (see slides for ray tracing)

$= -12\,(4\text{ cm})$

$= -48\text{ cm}$

24.2 Cameras

Film cameras are single lens reflex (SLRs).

Digital Single Lens Reflex (DSLR) cameras are mirrorless systems.

Ex. 24.3 $f = 50\text{ mm}$

a) For an object at infinity, ... b) For an object at 6m..

Lens equation:

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

∴ $q = f$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$= \frac{1}{0.050\text{m}} - \frac{1}{6\text{m}}$$

$$= 20.0\text{m}^{-1} - 0.167\text{m}^{-1}$$

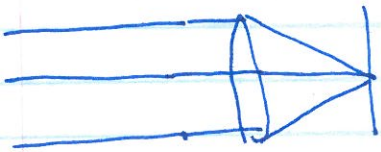
$$= 19.83\ \text{m}^{-1}$$

$$= 0.0504\text{ m}$$

$$= 50.4\text{ mm}$$

$p = \infty$

$\frac{1}{p} = 0$



parallel rays coming in at infinity (∞)

Lens needs only adjust by 0.4 mm

Regulating Exposure

Diaphragm regulates size of the aperture and controls how much light enters.

The shutter is the mechanism that regulates the exposure time, the time during which light is allowed to enter.

Continued next class....