

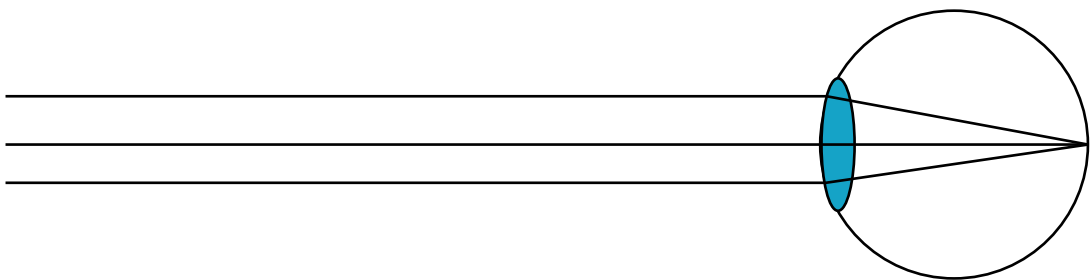
accommodation: to look at objects at different distances, the eye has to focus differently

distant object:

ciliary muscles
relaxed
(no forces)



relaxed lens,
has long
focal length

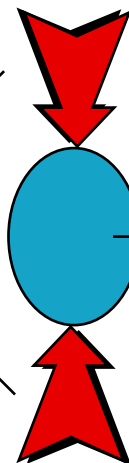


eye focussed on object "at infinity":
relaxed viewing

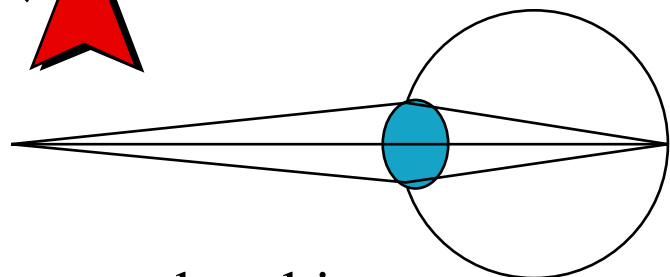
image of
object on retina

nearby object:

force exerted by
ciliary muscles



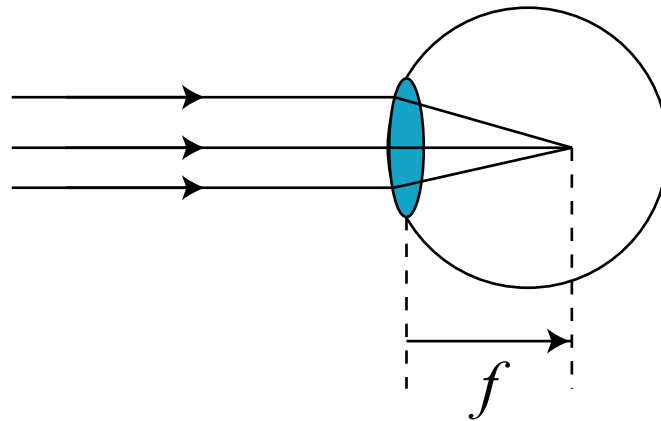
"squashed" lens,
has short
focal length



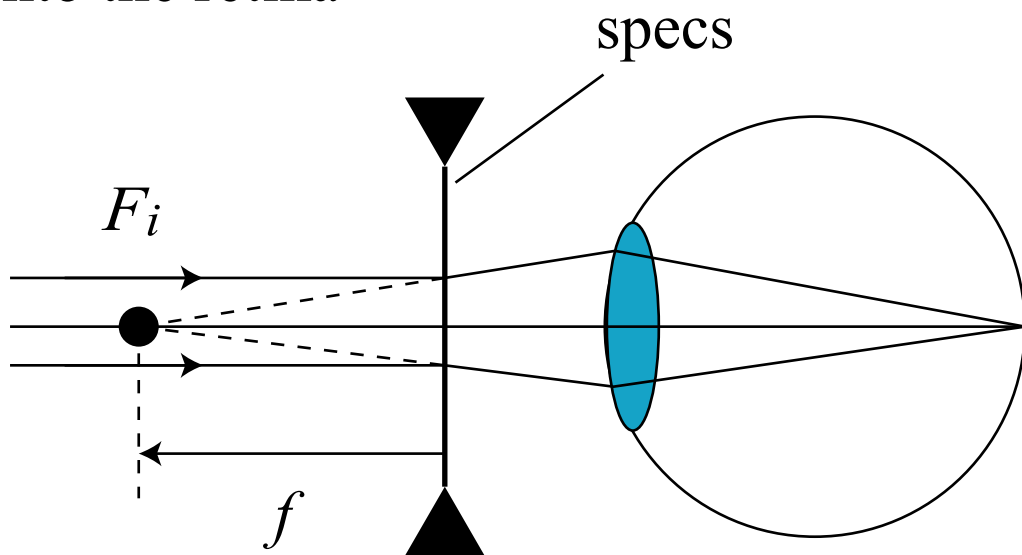
eye focussed on nearby object

the range of distances over which the eyes can focus gets smaller with age

myopia (short-sightedness):



even when the eye is relaxed, the lens's focal length is too short to focus very distant objects onto the retina



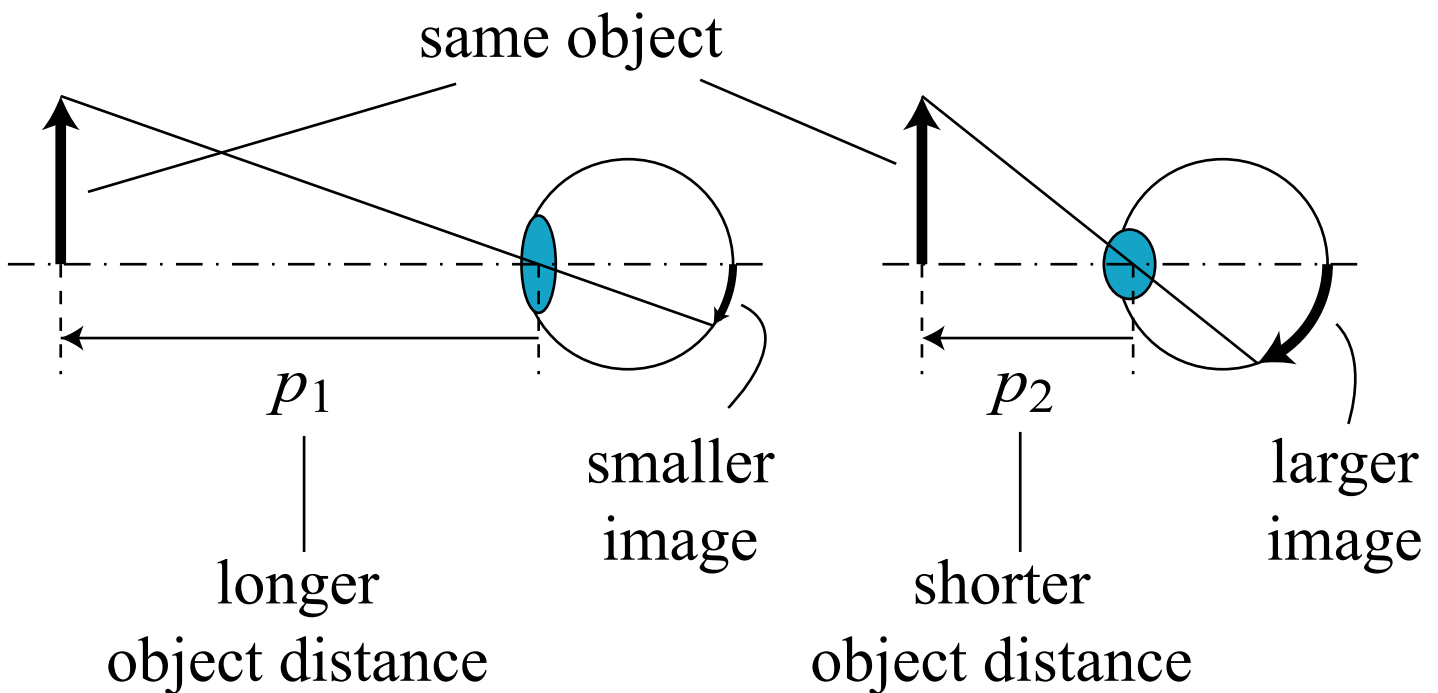
concave lens makes objects at infinity appear in its focal plane

more eye conditions: Benson 36.5 p. 751

1.5.2 Simple magnifying glass & angular magnification

Benson 36.2

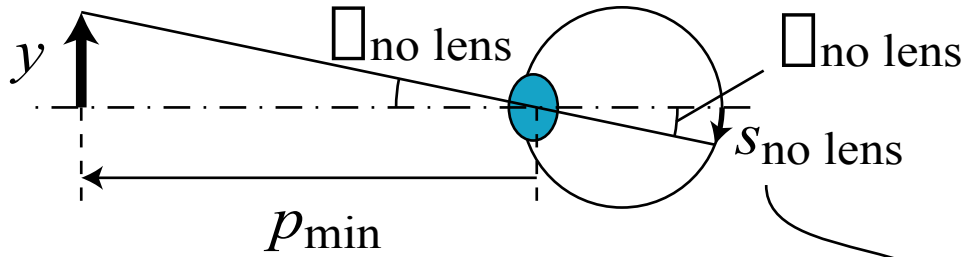
Why do we sometimes need them? Can't we just get a bit closer to the object and see it larger?



In principle yes, but in practice there is a limit to how close the eyes can focus, i.e. there is a shortest object distance, p_{\min} , at which the eyes can still see an object in focus (i.e. not blurred).

We use the value $p_{\min} \approx 25\text{cm}$.

without visual aids, an object is seen largest at the minimum viewing distance, p_{\min} :



with a lens of focal length $f < p_{\min}$:

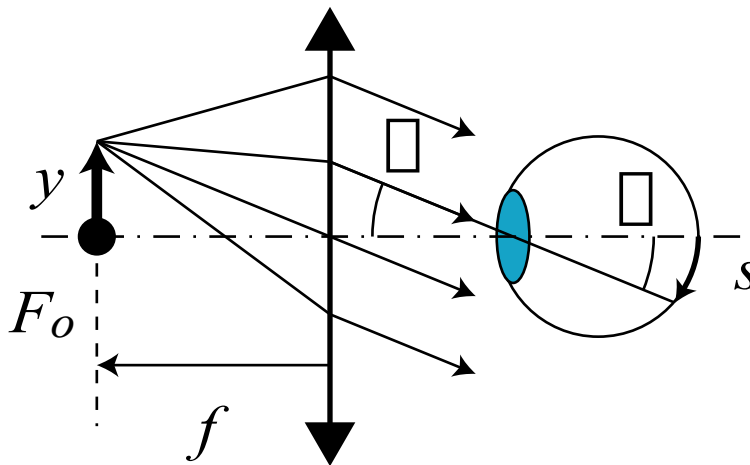
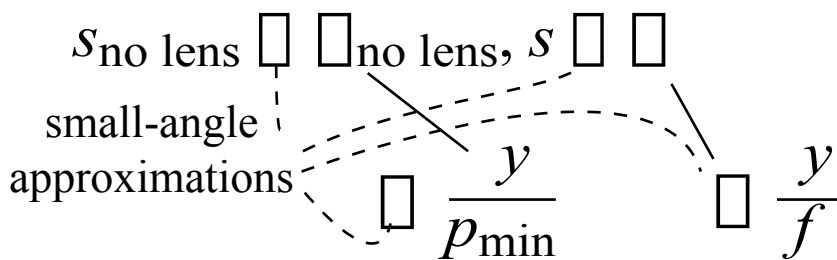
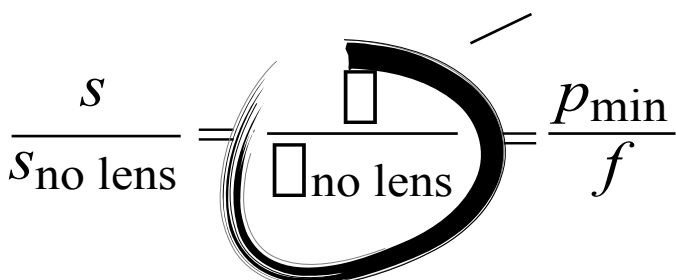


image sizes

calculate relative image sizes:



angular magnification, M

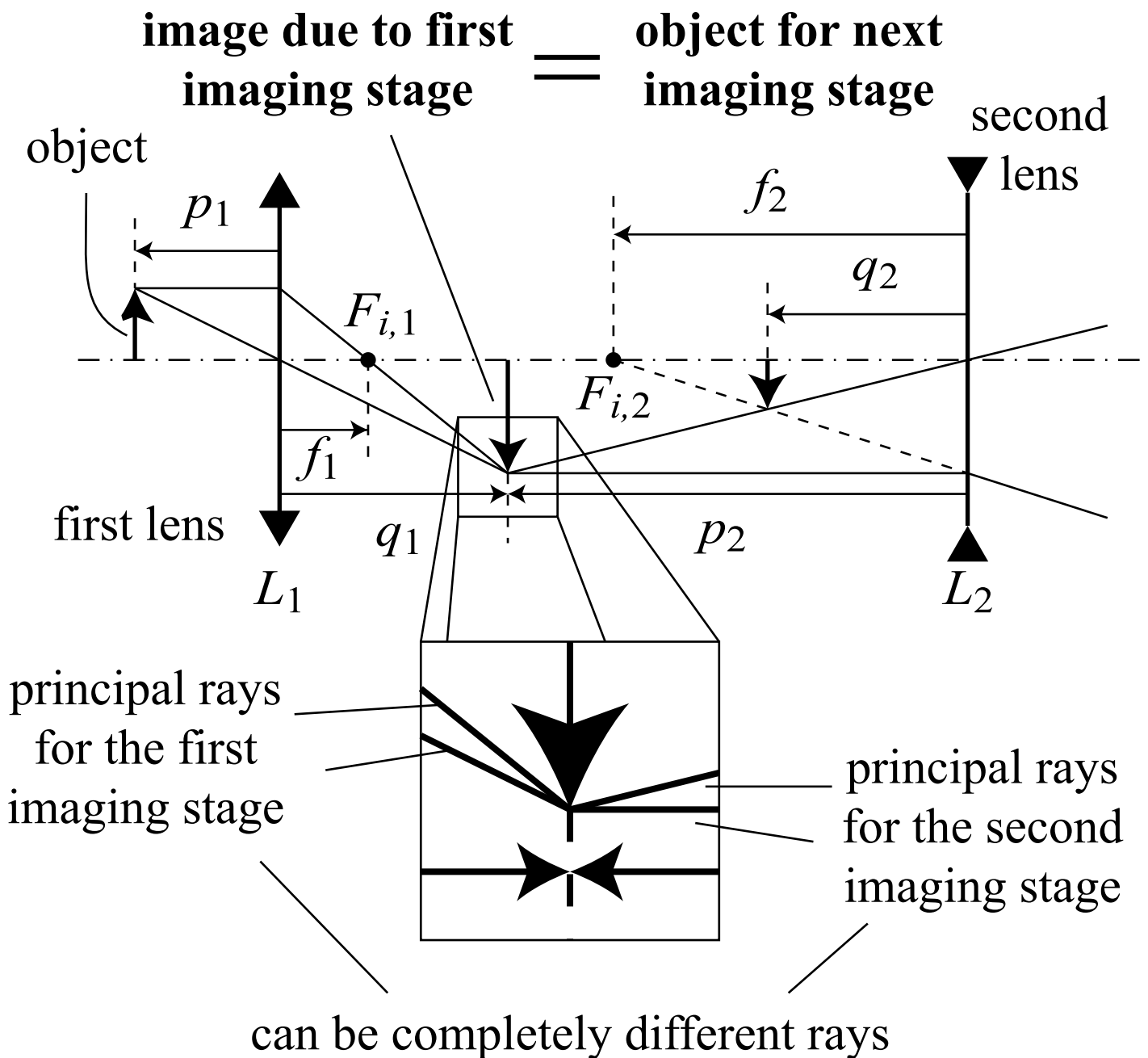


$$S = s_{\text{no lens}} \cdot M$$

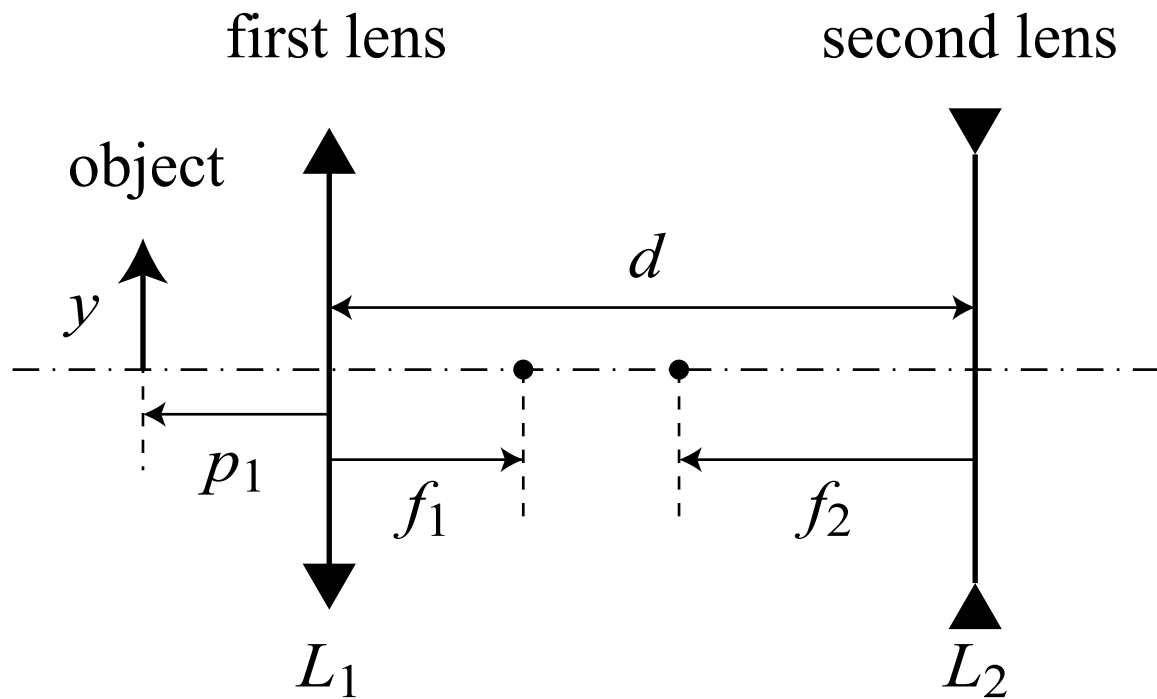
1.5.3 Combinations of lenses/mirrors

Benson 36.1 "Problem Solving Guide for Lenses", p. 743

treat the imaging due to the individual lenses and/or mirrors (*imaging stages*) **sequentially!**



completely general calculation of the image position and magnification due to TWO lenses:



known: focal lengths of two lenses, f_1 and f_2 (which can take on any value, positive or negative; don't be confused by the fact that I have drawn one the case $f_1 > 0$ and $f_2 < 0$), the separation between the lenses, d , the object distance w.r.t. the first lens, p_1 , and the initial size of the object, y

we consider the effect due to the two lenses one after the other, i.e. we split the problem into two parts

part 1: imaging stage 1 (i.e. effect of first lens, L_1)

first we calculate the position of the image produced by L_1 , i.e. its image distance, q_1

thin-lens formula

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

re-arrange:

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

$$q_1 = \frac{f_1 p_1}{p_1 - f_1} \quad \text{image distance 1} \\ \text{(behind first lens)}$$

by what factor is that image produced by L_1 larger than the initial object? By the transverse magnification of that imaging process

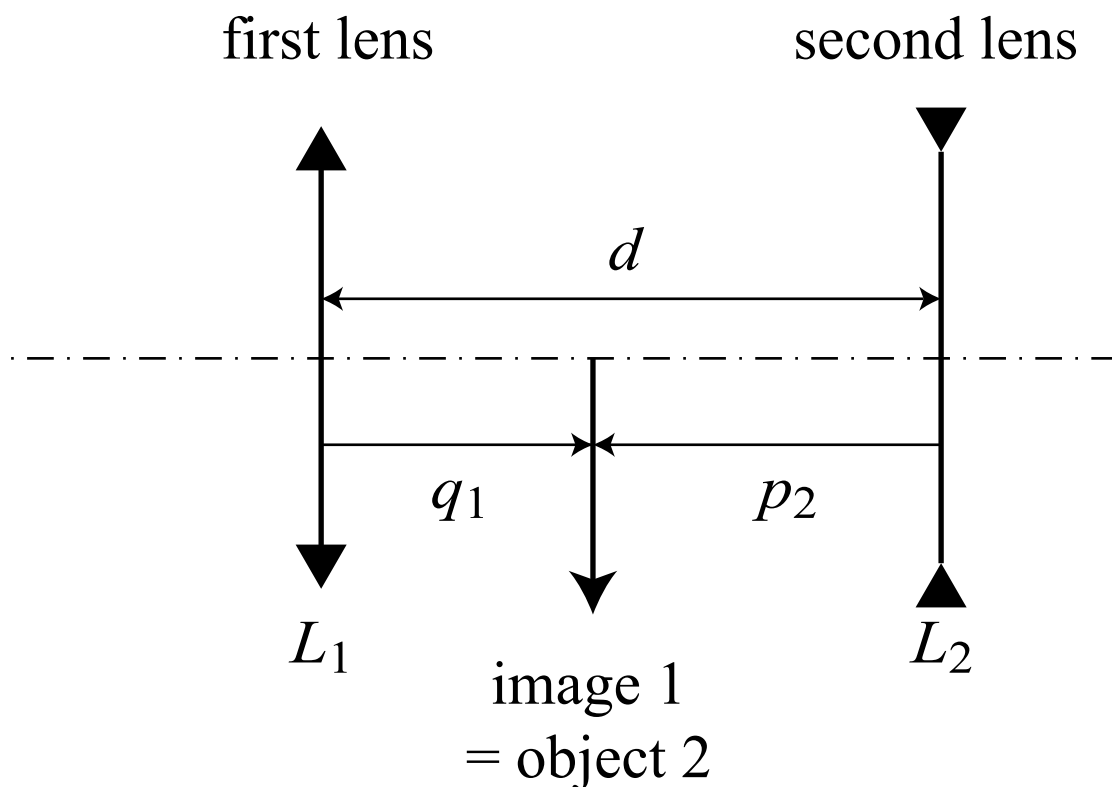
formula for transverse magnification

$$m_1 = -\frac{q_1}{p_1} = -\frac{f_1}{p_1 - f_1}$$

the image produced by the first imaging stage (and we now know all we need to know about this "image 1") acts as the object for the second imaging stage ("object 2")

part 2: imaging stage 2 (i.e. effect of the second lens, L_2)

the object distance p_2 for this second imaging stage can be calculated from the image distance p_1 in the first imaging stage



$$p_2 = d - q_1$$

$$= d - \frac{f_1 p_1}{p_1 - f_1} \quad \text{object distance 2} \\ \text{(in front of 2nd lens)}$$

if we change all the indices from '1' to '2' in the equations for the image distance and the magnification due to the first imaging stage we get the equations for the image distance and the magnification due to the second imaging stage (both in terms of the second object distance and the focal length of the 2nd lens)

$$q_2 = \frac{f_2 p_2}{p_2 - f_2} \quad \text{image distance 2} \\ \text{(behind second lens)}$$

$$m_2 = - \frac{f_2}{p_2 - f_2} \quad \text{magnification due} \\ \text{to 2nd imaging stage,} \\ \text{i.e. factor by which} \\ \text{image 2 (the final} \\ \text{image) is larger than} \\ \text{object 2 (which is the} \\ \text{same as image 1)}$$

