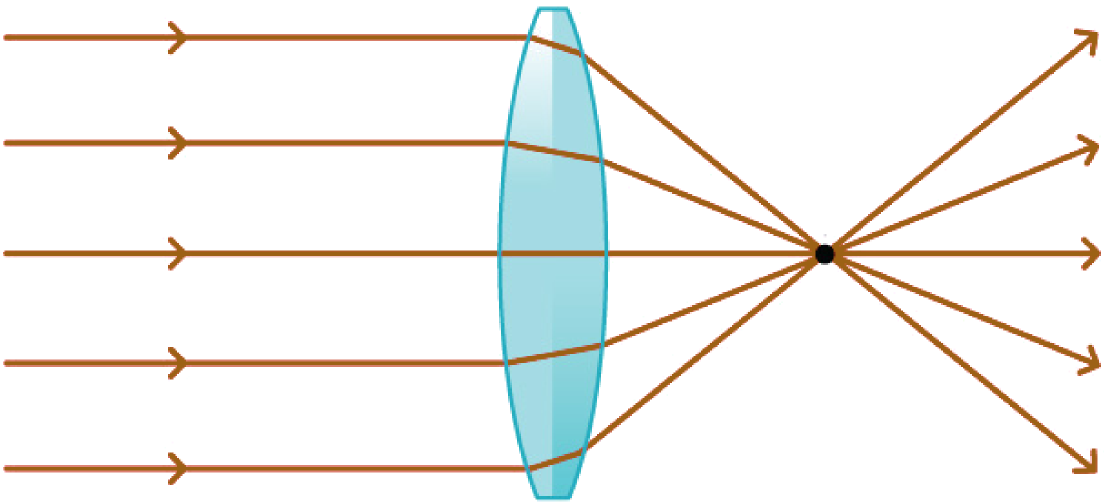
Lund University

O4: Geometrical Optics

Optics and Waves



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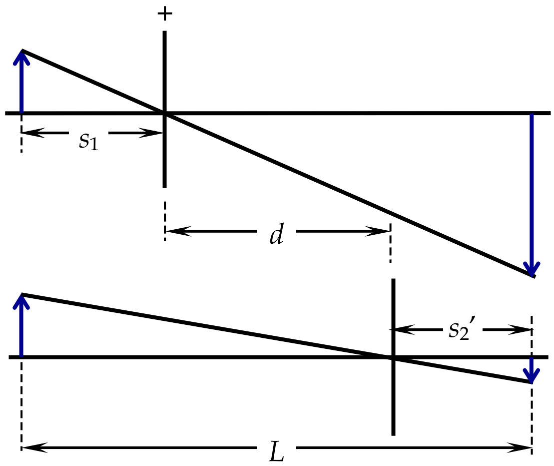
Preparations

Read the textbook chapters 34.3 through 34.8. Then solve the following problems and read through the entire instruction. Proper solutions are to be handed in before you start your lab.

1. The focal length of a positive lens can be determined as follows. If the distance L between object and image is larger than $4f$, there are two lens positions giving a sharp image. Call the distance between the two possible positions of the lens d. (See figure to the right.) Using L and d, f can be determined.



Explain why $s_1 = s_2'$ and show, using this and the lens formula, that

$$f = \frac{L^2 - d^2}{4L}$$

2. A positive lens is put on an optical bench. The optical axis is an x-axis, and the positive lens is placed at x = 0 mm. The image from the positive lens then occurs at x = 1200 mm.
If now a lens L2 is set at x = 1000 mm, the image from L1 will be "imaged" by L2 and the final image occurs at x = 1400 mm. Determine the focal length of lens L2.

3. To determine the size of the image sensor and a pixel in an iPhone SE, a photo of two crossed rulers was taken. The rulers were placed 215 mm from the camera lens. When looking at the picture, 261 mm of the horizontal and 196 mm of the vertical ruler was seen. Use the table to answer the questions below. The camera objective can be treated as a thin lens.

a) How far from the lens' focal point should the image sensor be placed for the image to be sharp?

b) What is the approximate size of the active area of the camera's image sensor?

c) The pixels in the image sensor are square. How big is a single pixel? Assume that the pixels are distributed only over the active area of the image sensor.

Cell phone	*f* / mm	#/ Mpx
Apple iPhone 4	3,85	5
Apple iPhone 4S	4,28	8
Apple iPhone 5	4,10	8
Apple iPhone 5C	4,28	8
Apple iPhone 5S	4,12	8
Apple iPhone 6, plus	4,15	8
Apple iPhone 6S, plus	4,15	12
Apple iPhone 7, plus	4,0	12
Apple iPhone SE	4,0	12
Google Pixel, XL	4,67	12,3
HTC One M8	3,82	4
HTC One M9	4,73	20,1
HTC 10	4,58	12
LG G2	4,0	13
LG G4, G5	4,42	16
Nexus 4	4,6	8
Nexus 5	4,0	8
(Huawei) Nexus 6P	4,67	12,3
Samsung Galaxy S3	3,7	8
Samsung Galaxy S4	4,2	13
Samsung Galaxy S5	4,8	16
Samsung Galaxy S6, Note5	4,3	16
Samsung Galaxy S7	4,2	12
Samsung Galaxy S8	4,2	12
Sony Xperia Z	4,1	13,1
Sony Xperia Z1	4,9	20,7
Sony Xperia Z2	4,9	20,7
Sony Xperia Z Ultra	3,0	8

During the day, you will do a number of experiments, all of which are applications on what we call geometric optics. The geometric optics assumes that we can neglect wave-related phenomena such as diffraction, and use the fact that light propagates in a straight line.

1 Properties of thin positive lenses

Place a light source, an object, the lens labelled L1 and a screen on the optical bench. Make sure the distance between the object and the screen is greater than 1 meter. Create a sharp image of the object on the screen. Note that there are two possibilities - a "projector mode" and a "camera mode", see problem 1. Use the projector mode and measure, as accurately as possible, the distances needed to determine the focal length f_1 of lens L1. Also be sure to determine the lateral magnification m of the image.

Then determine the focal length using the method described in Problem 1. Note that d is the distance between the lens' position in the projector and camera mode respectively.

Use any of the methods to determine the focal length and power of one of the positive eyeglass lenses.

Now, using the L1 lens, we will create an image with the lateral magnification $m = -1$. What does it mean having a magnification of 1? What does the minus sign tell us? Create an image with $m = -1$. How big is the distance $s + s'$ between object and image? How many focal distances f_1 does this correspond to? Show by using the lens formula how big the distance is expressed in f_1.

2 Properties of thin negative lenses

Determine focal length f_2 of lens L2 by means of lens L1 according to the method used in Problem 2.

Then use the same method to determine the focal length and the power of any of the negative eyeglass lenses.

3 The telescope

Build, with the help of suitable lenses, a telescope with the angular magnification $M = 4$. Calculate the length of the telescope comprising the lenses you selected, and use this distance between the lens and the eyepiece. Adjust the lens distances so that the scale on the wall is sharp. Try to look at the scale simultaneously through the telescope and beside it, to make sure the angular magnification is 4. Draw a sketch showing the image formation in your telescope. Be careful to draw the rays correctly!

4 The cell phone camera

Determine, using the method in problem 3, the size of the active area of the image sensor in your cell phone camera. If you do not have any of the cell phones listed in the table - try googleing the focal length of the lens on your cell phone. Also calculate the size of the pixels. You can assume that these are quadratic.

5* The cell phone camera as a magnifier

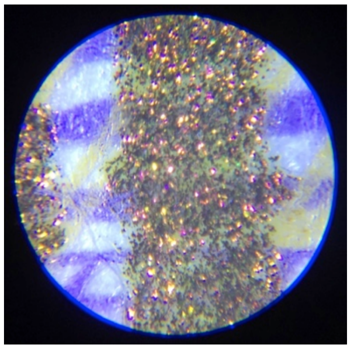
Make sure you understand how a magnifying glass works. Draw a ray diagram and convince yourself that you understand how angular magnification is defined.

Now, use your cell phone camera as an "eye". Then you do not need to think so much about where the image the camera will "see" ends up, but can concentrate on creating an image that the camera is able to image.

Start by determining how close to an item your cell phone can image sharply. Measure the distance, which we call the “near point”, as carefully as you can and estimate the maximum magnification you can achieve, by measuring objects and images.

The supervisor will supply you with three lenses of the type you see in the picture. Lens 1 is labelled "FISH-EYE LENS 180 °", lens 2 is labelled "0.67 × WIDE" and lens 3 "MACRO".

In order to be able to photograph very close to an object, and thus increase magnification, use the so-called Macro-lens (3). Put it into the clip and redo the measurements above. Finally, determine the focal length of the macro lens - the supervisor can guide you!



6* The cell phone camera as a microscope

In an optical microscope, you use a magnifying glass to enlarge the real image of a small object created by the objective. When looking through the microscope it is important that the image is infinitely far away, so that the eye stays relaxed.

The supervisor gives you a microscope designed for use with a cell phone. Start by just looking through the microscope. Do not forget to turn on the LED. Then attach the microscope to a cell phone and adjust the focus. How big magnification can you achieve?

The image to the right is taken with my cell phone - through the microscope. Can you see what it is? Can you enlarge it further?

7* More camera applications

If you combine lens 2 with lens 3 above, you get a so-called wide-angle lens. Examine lens 2 and determine its properties. Take a picture with the wide-angle lens on your cell phone. How much does the angular size increase?

The Fisheye (1) contains three different lenses. Disassemble it and examine the properties of the lenses. Be sure to keep track of how they are placed so that you can re-assemble the fisheye! Take a picture with the fisheye lens and estimate how much the angular size increases.