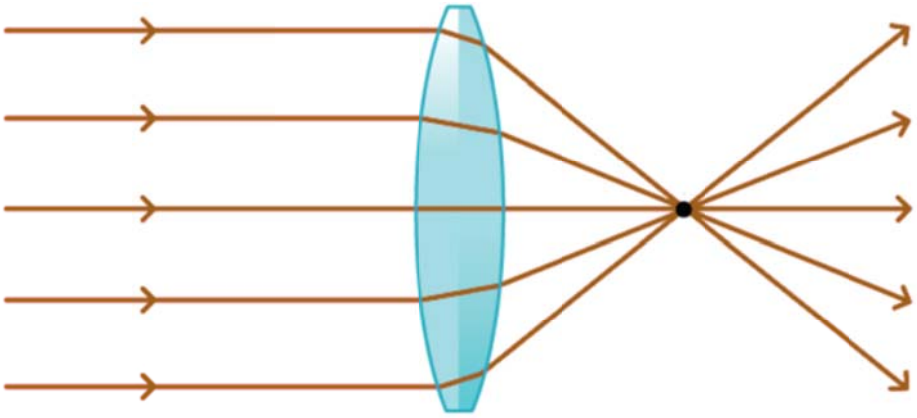
Lund University

O4: Geometrical Optics

Optics and Waves



Introduction

The lab is complete when you have suitable results in order to write your lab report. The lab report should be no longer than 10 pages and is due 5 days after the completion of the lab.

The preparation question is to be handed in before you start the lab.

Preparations

Read the textbook chapters 34.3 through 34.8. Then solve the following problems and read through the entire instruction.

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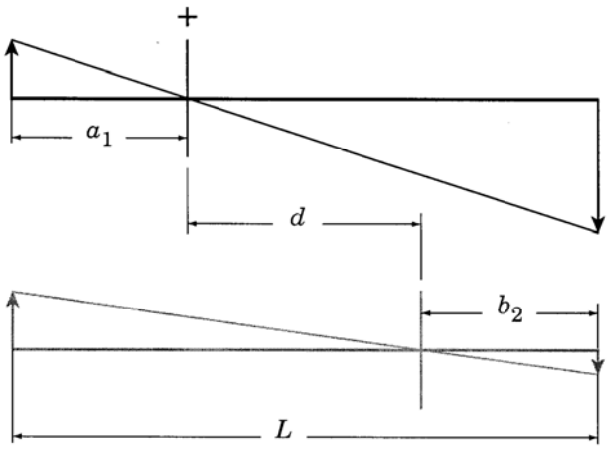
Solve the following problems

Proper solutions are to be handed in to your lab instructor 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 the figure.) Using L and d, f can be determined. Show that

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

Hint: Write down Gauss' lens formula with f, a_1 and b_1. Since $b_2 = a_1$ (due to



symmetry, see the figure), we obtain $L = 2a_1 + d$. Note also that $b_1 = L - a_1$.

2. A positive lens is put on an optical bench. If the optical axis is an x-axis, 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 act as an object for L2, and the final image will occur 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 5s, a photo of two crossed rulers was taken. The rulers were placed 365 mm from the camera lens. When looking at the picture, 115 mm of the horizontal and 86 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 camera's image sensor?

c) The pixels in the image sensor are square. How big is a single pixel?

Cell phone model	*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
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
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

Tabell 1. Data for some common cell phones.

Laboratory Assignment

Tasks 1 and 2 are carried out with the long optical benches, and tasks 3, 4 and 5 are carried out with the short ones.

1. Properties of thin positive lenses

a) 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.

b) 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.

c) Use a method of your choice to determine the focal length and power of one of the positive eyeglass lenses.

d) Now, calculate the sum of the object and image distances $a + b$ and express it in focal lengths of lens L1, when the lateral magnification is $M = -1$. Check your result using the optical bench.

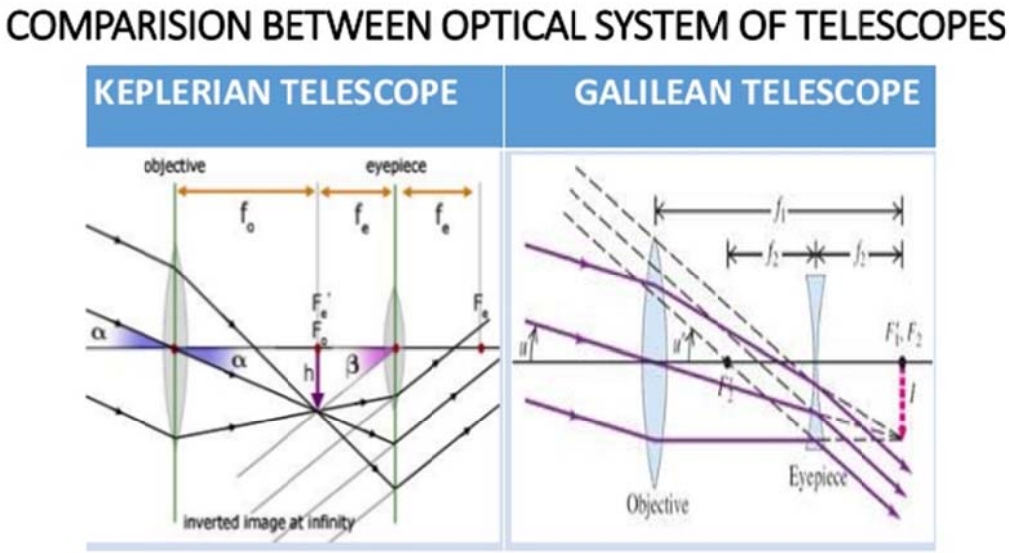
2. Properties of thin negative lenses

a) Determine focal length f_2 of lens L2 by means of lens L1 according to the method used in Problem 2.
b) Determine the focal length and the power of any of the negative eyeglass lenses.

3. Galilean telescope

a) Build, by using suitable lenses, a Galilean telescope with the angular magnification $G = 3$. Calculate the length of the telescope comprising the lenses you selected, and use this distance L 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 (with both eyes open) through the telescope and beside it, to make sure the angular magnification is 3. Draw a sketch showing the image formation in your Galilean telescope. Be careful to draw the rays correctly!

b) Build, by using the same lenses as in task (a), a telescope with the angular magnification $G = 1/3$. In what context is this type of telescope used?



4. Kepler telescope

a) Build, by using suitable lenses, a Kepler telescope with the angular magnification $G = 4$. Calculate the length of the telescope comprising the lenses you selected, and use this distance L 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 (with both eyes open) through the telescope and beside it, to make sure the angular magnification is 4. Draw a

sketch showing the image formation in your Kepler telescope in its normal adjustment. What are the main differences between the Kepler telescope and the Galilean telescope?

b) Now, use three positive lenses with the focal lengths 50 mm, 100 mm and 200 mm and build a terrestrial telescope, i.e., a Kepler telescope with an erecting lens ($M = -1$) between the objective and the eyepiece. Start by calculating the distances and make the telescope as compact as possible!

5. Microscope

Build a microscope at normal adjustment, by using two positive lenses with the focal lengths 50 mm and 100 mm. The tube length (the distance between the objective's and eyepiece's focal points) is to be 160 mm. Calculate the magnification of the microscope and check if the answer is reasonable by "using" the microscope. Use a lit frosted glass plate as an object and adjust the microscope image by moving the object.

6. Digital camera /Cell phone camera

a) Determine, by using the method in problem 3 (Preparations), how large is the image sensor in a digital camera, or in your own cell phone camera.

b) Calculate the size of the pixels. You can assume square pixels.

7. Color composition of pictures on screens and pictures in print

a) In the folder named "Geometrisk optik" on S:\ you will find a picture called "Laos". Open the picture in Paint. Use a magnifying glass to study the picture on the screen. What colors does the screen produce? Describe the color content of a white, black and yellow area in the picture.

b) Open the photo named "Färger" in Paint. Analyze the color content in respective field by using the eyedropper tool (click the eyedropper-shaped icon in the "Tools" section); click with it on the color you want to analyze. The three coordinates R, G and B of the color will be then given. In a perfectly red area, we have R = 255, G = 0 and B = 0. That is, here all the red points glow with maximum intensity while all the green and blue points are switched off (minimum intensity is thus 0). What are the names of the three colors in the central line and how are these colors built up?

c) Inspect a banknote and a picture in a printed newspaper, by using a magnifying glass. What colors are the pictures composed of? How is a banknote and a newspaper, respectively, printed?