Physics exam - SCAN FIRST

October 15, 2021 (1 h)

No document allowed. No mobile phone. Any type of calculator allowed. The proposed grading scale is only indicative. The marks will account not only for the results, but also for the justifications, and the way you analyze the results. Moreover, any result must be given in its literal form involving only the data given in the text. It is also reminded that the general clarity and cleanness of your paper may also be taken into account.

Exercise 1 : Focimetry ($\simeq$ 15 points)

Focimetry is the art of measuring focal lengths of centered optical systems using paraxial approximation. In this exercise, we will focus on 2 different methods.

Part 1 : Silbermann's method

A converging lens L_1 of optical center O_1 is placed in air. We want to measure its focal length f_1' using Silbermann's method.
The lens L_1 gives an image $A'B'$ from a real object AB. During the experiment, the distances are chosen such that the image is reversed and has the same size as that of the object.

1. Using a ray-diagram, find the relation between the focal length f_1' and the object-to-image distance $D = \overline{AA'}$.
2. Find the same relation, this time by calculation.
3. Does this method work for any kind of lens ? Briefly explain your opinion.

Part 2 : Badal's method

We now want to measure the focal length of lens L_2 using Badal's method.

The following experiment is carried out with 2 converging lenses L_a and L_b, centered on the same optical axis. The focal length of lens L_b is $f_b' = \overline{O_bF_b'} = 20$ cm.

- A point source A is placed in the object focal plane of lens L_a ;
- Its final image A' is observed on a screen placed in the image focal plane of L_b ;

1. Propose an experimental method (explanation + ray diagram) to place A precisely in the object focal plane of lens L_a.
2. Complete the ray diagram in Figure 3 and find the position of A'.

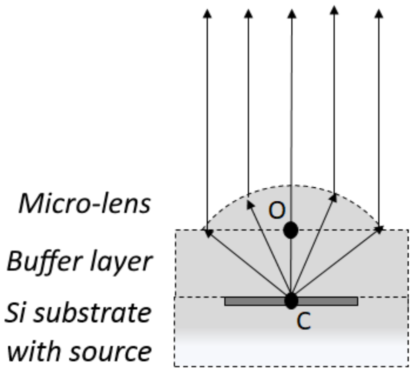
The thin lens L_2, of center O_2 and unknown focal length f_2', is now placed in the object focal plane of the lens L_b. In order to observe the new image A', it is necessary to move the screen S.

3. By calculation or using a ray diagram (given in appendix), give the literal expression of the focal length f_2'.
This is an open question. You have to extract the useful pieces of information, eventually formulate hypotheses and explain your approach. Any relevant element will be valued even though you do not get the final result.

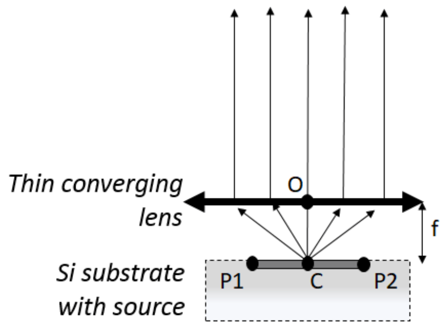
4. Numerical application : during an experiment, the screen had to be moved further away from lens L_b, by a distance $d = 12$ cm. Give the nature of lens L_2 and the value of its focal length.

Exercise 2 : Micro-lens and optoelectronics ($\simeq$ 5 points)

In optoelectronics, electric signals are converted into optical ones, and vice versa. One major problem in optoelectronics remains to extract efficiently light from electric components. Indeed, most of the optoelectronic devices are made in silicon (Si), a semiconducting material having a high optical index. Silicon emits photons when an electric current flows through a junction between two regions having different dopant concentrations. Such device is called "light-emitting diode" (LED). It can be found in smartphone screens, for instance. In this exercise, it is not important to understand how the device works. It will be considered as a plane source of light. Each point of the device emits light in all directions.



(a)



(b)

FIGURE 1 – schemes of a LED and a microlens. a) real scheme. b) approximated scheme. In both cases, the rays emitted by point C are shown. These rays give parallel vertical rays after the lens.

Surface micro-lenses can be used to increase the intensity of light emitted by such sources. The focal length of these micro-lenses is designed to send light along specific directions in air. The studied micro-lens is placed such that the source plane lies in its object focal plane (this is achieved by choosing the right thickness of the buffer layer, see Figure 1a). In the following, a simplified optical system will be considered, see figure 1b. In such simplified scheme, the micro-lens in silicon is replaced by a converging lens in air. The plane source is still in the lens object focal plane.

We want light to be visible without any accommodation, for a given range of angles. In the case studied here, we want light to form a vertical cone of angle 45°, as shown in Figure 2.

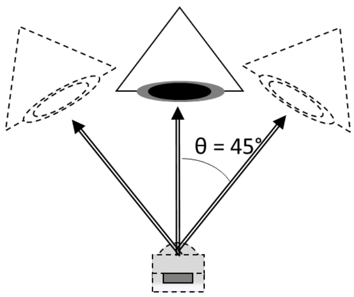


FIGURE 2

Compute the focal length f' required for the micro-lens in air, knowing that the source diameter is $P_1P_2 = 10\ \mu$m. Propose a ray-diagram to show how the rays emitted by the end points P_1 and P_2 are deviated by the lens and form beams at 45°from the vertical.

In this open question, we appeal to your ability to construct sketches from the diagrams given in Figures 1 et 2 and the information contained in the text presented, and to analyze the latter to configure the device studied. You will be graded on your reasoning skills, so it is important to comment on the validity of any assumptions on which you base your answers.

APPENDIX

Last name, first name :

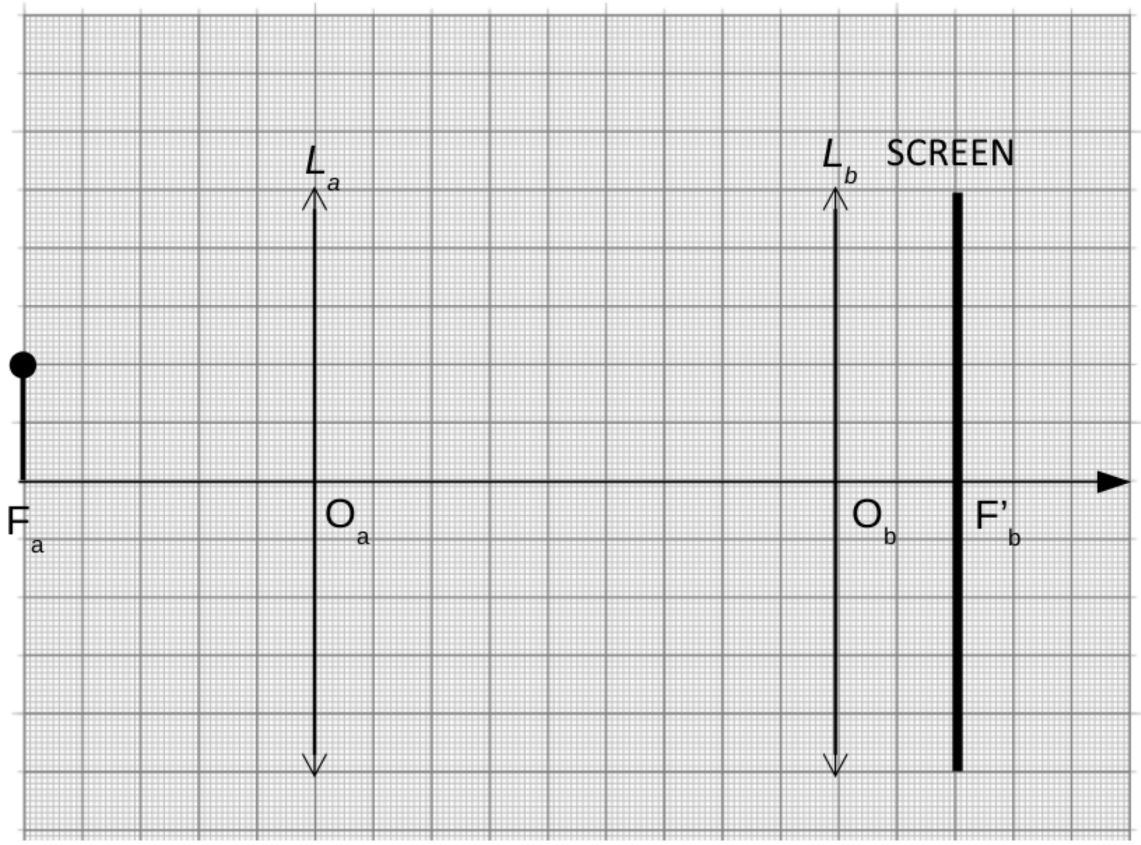


FIGURE 3 – Ray diagram for Badal's method

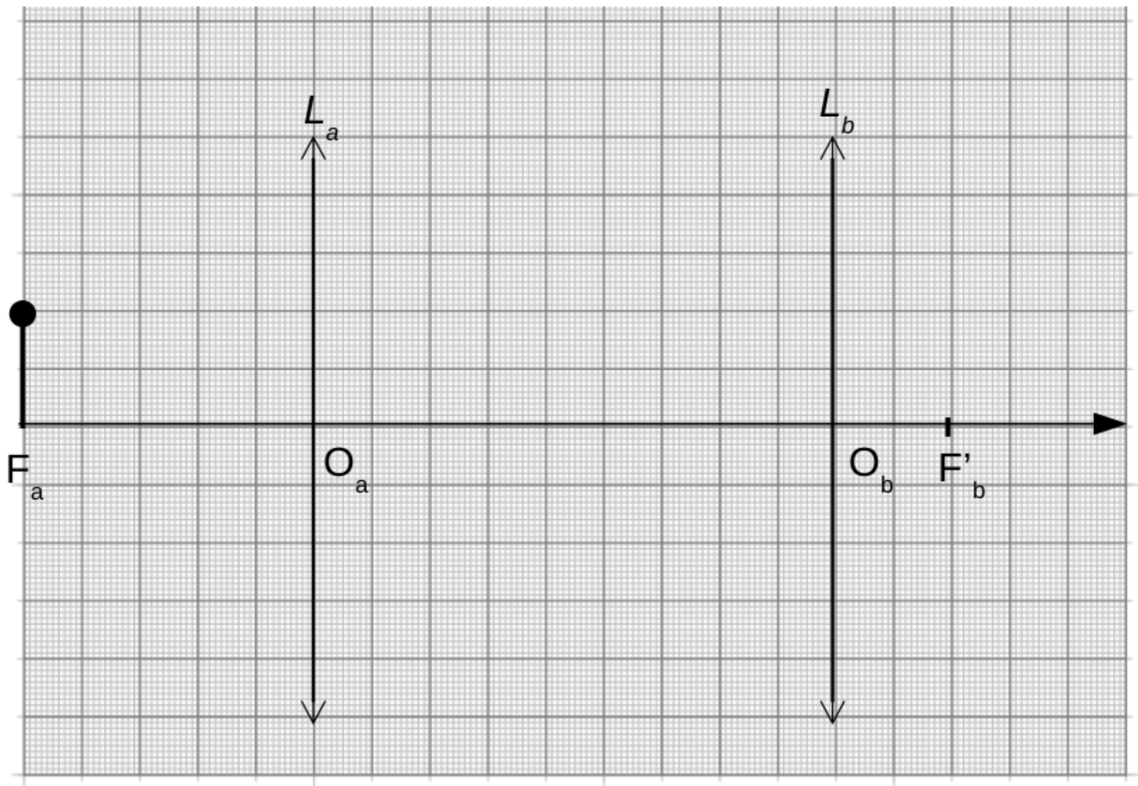


FIGURE 4 – Supplementary ray diagram for Badal's method