Exam #1 – Physics

Friday, October 13, 2017 **Duration: 1 h**

No documents allowed. No mobile phone. The use of not-programmable calculator is allowed. The marks will account for the justifications, the writing and the general clarity and cleanness of your paper. Indicative grading scale.

Exercise 1 – Lenses (≈ 8 points)

Both parts are independent from each other.

Where should the lens be placed?

We consider an object *AB* and a lens *L*. We want to find the position of the real object *AB* so that the image is reversed with the same size.

1. By calculation, find the expression of the object position $\overline{OA}$ as a function of the lens focal length *f'*.
2. Deduce the nature of the lens (converging, diverging?). Explain your answer.

Ray-diagram

An optical system is composed of two thin lenses L_1 and L_2, of focal lengths $f'_1 = -5\ cm$ and $f'_2 = +4\ cm$ under paraxial conditions. The distance between both optical centers is equal to $\overline{O_1O_2} = +11.5\ cm$. We want to find the image *A'B'* of an object *AB* placed at $\overline{O_1A} = +3\ cm$ through the optical system.

1. With the help of a scheme, propose a method to create the virtual object *AB*.
2. On Figure 1, trace the **complete** path (= through both lenses) of **three** rays coming from point B. Indicate also the intermediate image $A'_1B'_1$.

Exercise 2 – To make it clear (≈ 12 points)

Until the XIX^e century, it was difficult to light and guide boats situated far away from the lighthouses. The first lighthouses were composed of woodfires on platforms, then of an association of a candle and a mirror. They gave a poor luminous intensity. In 1822, Augustin Fresnel replaced the mirrors by a newly developed lens, the Fresnel lens.

A Fresnel lens is composed of a converging lens surrounded by prismatic rings (see Figure 2 and Figure 3). Thanks to its geometry, it is possible to obtain a short focal length with a large diameter. The lens is not as heavy as a single converging lens of equivalent focal length.

In this exercise, we will first study the converging lens at the center of the Fresnel lens. Then, we will study the prisms. **Both parts are independent from each other**.

Study of the converging lens and considerations on the light source (≈ 4 points)

1. The aim of the Fresnel lens is to provide light to boats located far away from the lighthouse. Where should you place the point light source (S) with respect to the optical center O of the lens? Explain your answer.

2. Why is it not possible to use a diverging lens? Explain your answer.

3. Give the conditions for paraxial approximation in the case of a thin lens. Deduce why it is not suited to use a single lens of large diameter to guide boats.

4. The range of a lighthouse is also limited by light absorption and scattering. Indeed, the small particles present in the atmosphere absorb and scatter light in all the directions of space. As a consequence, a significant decrease of intensity occurs in the initial direction of propagation.

   The scattering power can be expressed as $P_{scat} \sim \frac{K}{\lambda^4}$, where K is positive, and constant for a given incidence angle. Is it better to use a red or a blue light source for large-range lighthouses? Explain your answer.

Study of the prisms surrounding the converging lens (≈ 8 points)

Each prismatic ring can be modeled by a prism of index n, apex angle A and having a vertical entry side. In the following, it can be considered that $n_{air} = 1$. The angles will not be oriented so all angles will be considered as positive.

A ray of light arrives on the vertical entry side of the prism with the incidence angle i_1. D is its total deviation at the exit of the prism (see Figure 4).

5. Knowing that the prism geometry imposes $A = r_1 + i_2$, show that the total deviation D can be expressed as $D = i_1 + r_2 - A$. You can first express the deviations of the ray after each refraction (see Figure 5).

6. a) With the help of Figure 2 and Figure 4, express the relation that D and i_1 have to fulfill so that the optical system can be used to light boats situated far away from the lighthouse. Explain your answer.

   b) bonus question : Deduce an approximated expression for r_2. Do you think it is possible to use the same prism geometry for all angles i_1? Explain your answer.

7. We consider a ray arriving perpendicular to the entry side of the prism. The incidence angle is therefore $i_1 = 0$. In this question, we use $n = 1.7$ and $A = 40°$.

   a) Trace the path of the ray on Figure 6. Explain carefully what happens on each diopter the ray meets, and give the values of each angle.

   b) Deduce why it is not possible to use prisms of angle $A = 40°$ for small values of the incidence angle i_1 (in particular at the center of the optical system, instead of the lens).

NAME and GROUP : ………………………………………….

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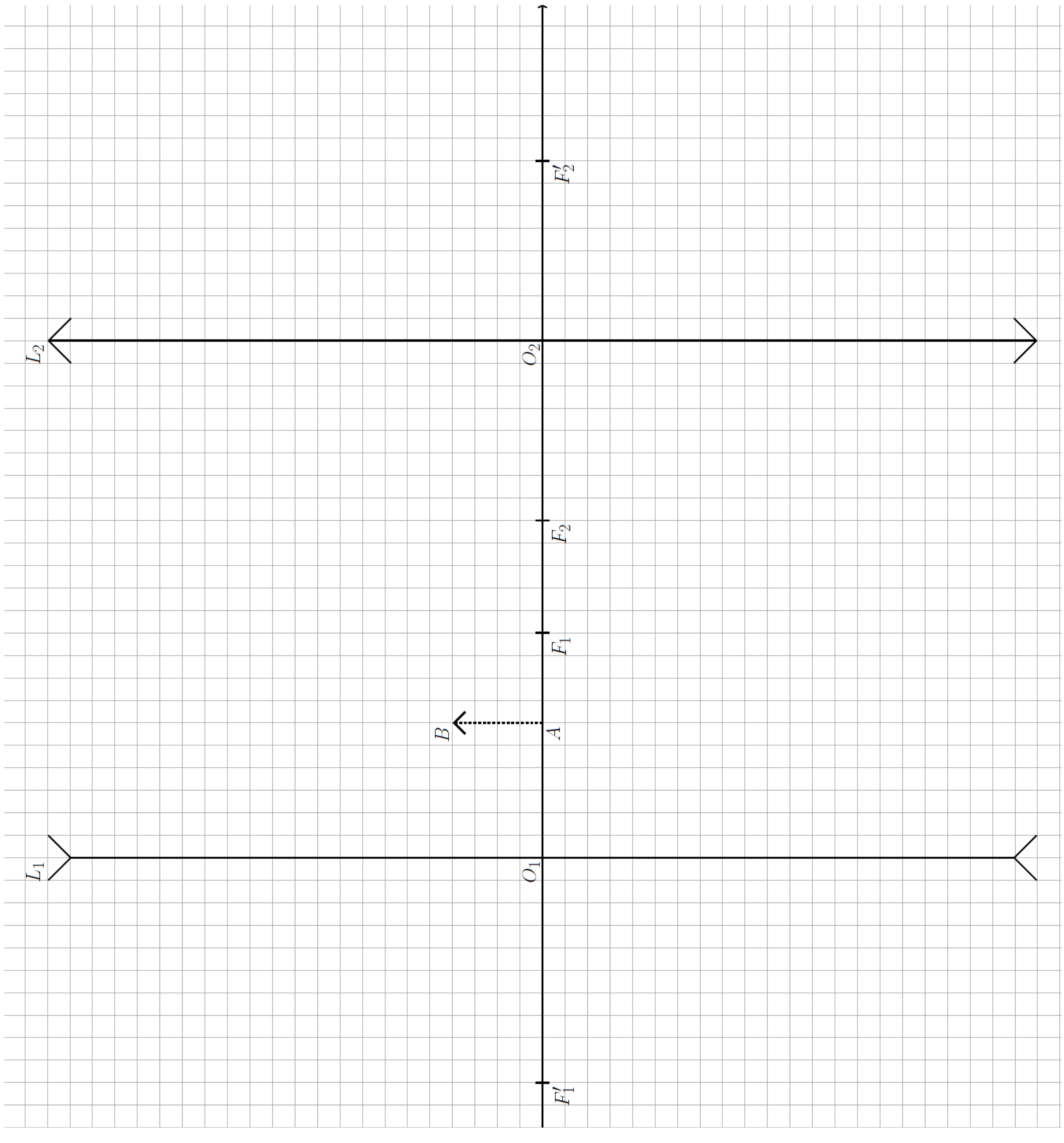

Figure 1 : ray-diagram to be completed

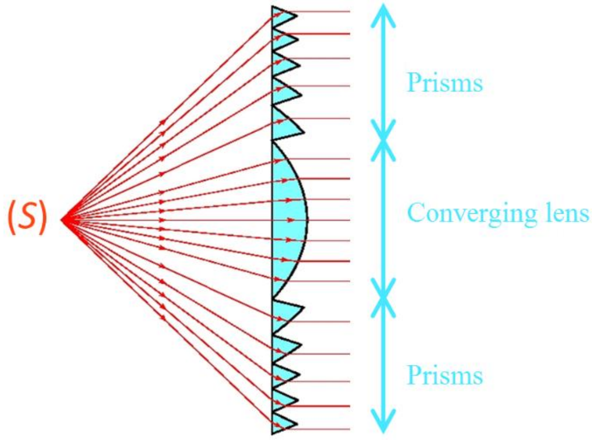

Figure 2: scheme of a Fresnel lens (cross-section)

Figure 3: picture of a lighthouse
http://www.breizhorizons.com/D.Grimberg

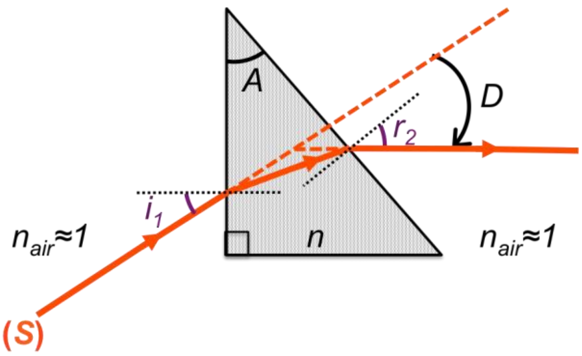

Figure 4: Path of a ray through a prism

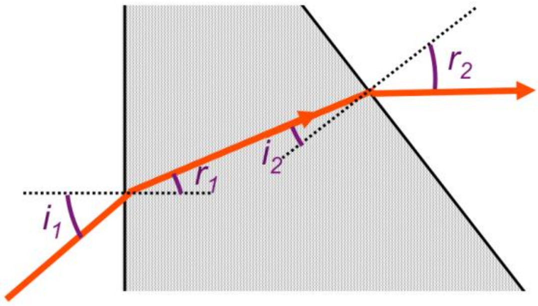

Figure 5: zoom on both incidence points

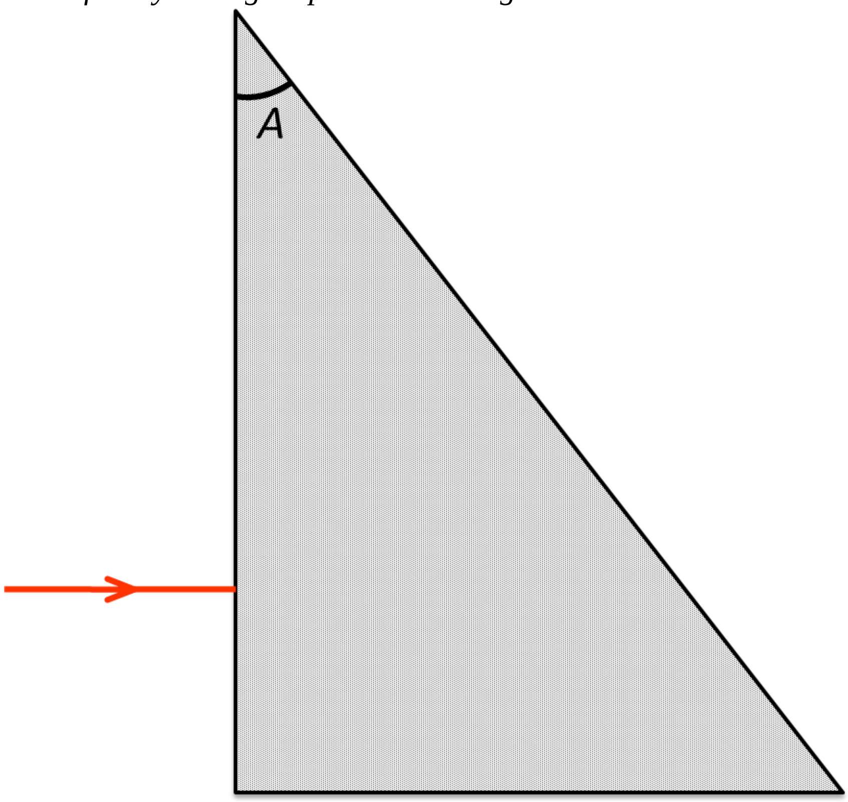

Figure 6: path of the ray to be completed