Exam #2 – Physics

Friday, November 21, 2014 **Duration: 1 h 30**

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 papers. Indicative grading scale.

1- Study of a photocopier enlargement-reduction system

This exercise deals with the study of a photocopier enlargement-reduction system. The aim is either to enlarge a document from size A4 (21,0 cm x 29.7 cm) to size A3 (29.7 cm x 42.0 cm), or to reduce it from size A3 to size A4. Because of the photocopier configuration, the images have to be formed at the same place.

An afocal optical system composed of 2 thin lenses can be used. In the following, one will consider two lenses L_{01} and L_2 of focal lengths $f'_{01} = 7.1$ cm and $f'_2 = 10.0$ cm, respectively. The distance e between both lenses is $= \overline{O_1O_2} = f'_{01} + f'_2$.

1. Draw (Document 1) the final image $A'B'$ of the object AB placed 8.1 cm in front of the lens L_{01}. Give an estimation of the magnification. Conclusion?
2. List the source(s) of uncertainty on this graphical measurement of the magnification.
3. Give the literal expression of the final image position, $\overline{O_2A'}$, in function of e, f'_{01}, f'_2 and $\overline{O_1A}$.
4. Deduce the numerical value of $\overline{O_2A'}$.
5. Give the literal expression of the system magnification γ in function of f'_{01} and f'_2. Conclusion?

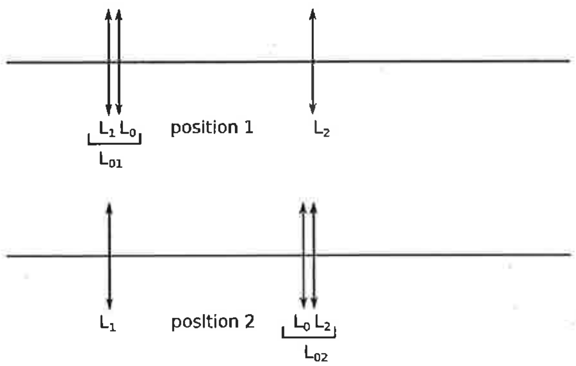

Figure 1

In fact, the lens L_{01} is composed of two thin lenses in contact with each other, L_0 and L_1 (position 1 on Figure 1). The focal length of the lens L_1 is equal to $f'_1 = 10.0$ cm. Using an appropriate command, the user can bring L_0 in contact with L_2 (position 2 on Figure 1). This creates a doublet L_{02} which can be considered as a single thin lens. The positions of the lenses L_1 and L_2 remain unchanged during the translation of L_0.

6. Let f'_0 be the focal length of the lens L_0. Show that for such doublet with lenses in contact with each other $\frac{1}{f'_{01}} = \frac{1}{f'_0} + \frac{1}{f'_1}$. Deduce f'_0.
7. Give the literal expression and the value of f'_{02} - the focal length of the new doublet L_{02}. Deduce the expression and the value of the new magnification γ' of the system. Conclusion?

8. Draw the path of the rays in this new configuration (Document 2) and check the value of the new magnification γ'.

9. Without any calculation (but with precise explanations!), determine the position of the new image. Comment. One may notice that $\overline{AO_1} \cong \overline{O_2A'}$.

2- Measurement of a focal length

A student wants to characterize a convergent lens L_0 which focal length is unknown. She can use a light source, an object, an optical bench and a screen. She performs the following measurements (Table 1) and draws the graph presented in figure 2 for the measurement of the lens focal length.

Lens-object distance p = $\overline{OA}$ (cm)	Lens-image distance p' = $\overline{OA'}$ (cm)	Δp (cm)	Δp' (cm)
-20.2	3.3	4	5
-15.4	3.7	4	5
-5.3	3.8	4	5
-8.3	4.8	4	5
-6.2	6.0	4	6
-5.5	8.1	4	6
-4.8	9.7	4	8
-2.1	13.6	4	10
-4	16.4	4	15

Table 1: raw data

1. Explain how the student could estimate Δp and Δp'.

2. Figure 3 presents a graph drawn with the student's data. Analyse the graph and deduce an estimation of *f'* with its uncertainty.

3. Give the literal expression of the horizontal uncertainties. Give the numerical value for the first point.

4. Propose another method based on the student's data for the determination of *f'*. Explain the method without applying it.

3- Vibration of a guitar string

The frequency *f* at which a guitar string vibrates depends on its length *l*, the intensity of the tension F applied to the string and its linear mass density μ :

$$f = \frac{K}{l}\sqrt{\frac{F}{\mu}}$$ where K is a constant.

1. Knowing that F (tension applied to the string) is a force and μ a mass per unit length, give the dimension of the constant K.

In a specification sheet, the tension on a guitar string is often given in kilogram-force (kgf). By definition, 1 kgf = 9.81 N.

2. A person wants to obtain a A440 (f = 440 ± 5 Hz, "*la*" in French) with a string of length l = 80.0 cm (relative uncertainty 3%) and of linear mass density μ = 0.030 ± 0.001 $g.cm^{-1}$. K is known to be equal to 2 (SI) without any uncertainty. Which value does one have to give to F, in N and in kgf? Give also the uncertainty on F in both units.