Exam 2 – Physics
November, 23^{rd} 2018, duration : 1h30

No document allowed. No mobile phone. The use of non-programmable calculator is allowed. The proposed grading scale is only indicative. Any result provided without units will be consider as false. The marks will account not only for the results, but also for the justifications, and the way you analyze the results. It is also reminded that presentation, clarity and spelling will be taken into account through a +/-1 bonus-penalty.
Return this document back with your exam paper.

Exercise 1 : Plot of an I-V Characteristics (6 points)

In order to study an active dipole, students from INSA have used the setup depicted in Fig. 1. Then, they changed the value of resistance R and measured the voltage difference across the dipole using a voltmeter whose relative uncertainty is 10 %. The current intensity flowing into the circuit was measured with an ammeter whose relative uncertainty is 8 %. Finally, they plotted the current-voltage characteristics on document 1.

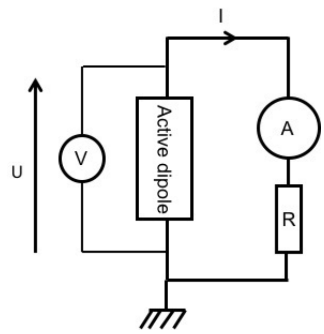


FIGURE 1 – Scheme of the experimental setup

1. Justify that the dipole is an active one.
2. Determine the equation of the straight line that can be used to model the characteristics of the dipole. Give the uncertainty on the parameters describing the straight line.
3. Give the equivalent circuit scheme of the dipole. Provide the value of each component together with their uncertainty and the direction of U and I.
4. Which convention has been used to plot the current-voltage characteristics ? Justify your answer.
5. Does this dipole always supplies energy ? Justify.

Exercise 2 : Galileo's telescope (8 points)

In 1609, Galileo Galilei had the idea to combine two lenses, a **converging** lens and a **diverging** one, and thus created what is now known as Galileo's telescope. This telescope is used to observe objects that are very far on the Earth surface and in the sky. It is an afocal optical system. We propose here to study some properties of that instrument.
Galileo's telescope consists in :

- an objective lens considered as a thin lens (L_1), of optical center O_1 and focal length $f_1' = 20,0$ cm.
- an ocular considered as a thin lens (L_2), of optical center O_2 and focal length $f_2' = -4,0$ cm.

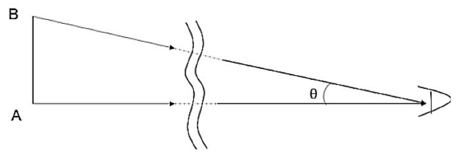
We note d the distance between the two optical centers : $d = \overline{O_1O_2}$. The focal lengths are known with a 2% uncertainty.

1. Optical scheme of Galileo's telescope

We want to use Galileo's telescope in Gauss conditions in order to observe an object very far away without accommodation.
1.1. How do L_1 and L_2 need to be placed ? Justify your answer.
1.2. Determine the value of distance d and the uncertainty on d.

1.3. On **document 2**, place L_2. We consider a ray of light reaching the telescope at angle θ with the optical axis. Represent on this same document the ray path through the entire telescope, as well as the intermediate image of an object at infinity making an angle θ with the optical axis.
1.4. Is the final image of an object at infinity upright or reversed? What are the advantages of using such telescope rather than an astronomical lens?
Reminder : an astronomical lens is made of two thin converging lenses of focal lengths f_1' and f_2' respectively, and it can be shown that the expression found for d is also valid for an astronomical lens.

2. Angular magnification of Galileo's telescope



We characterize an extended object AB located at infinity by its angular size θ, which is defined as the angle between the two lines coming from the object extremities towards the eye/the observer.

Given an object at infinity transformed into an image at infinity through an afocal system, we note θ' the angular size of the image through the system. The angular magnification (G) is then defined by : $G = \frac{\theta'}{\theta}$.
2.1. Show that $G = -\frac{f_1'}{f_2'}$.
2.2. Determine the value of G and the uncertainty on G.

3. Open question : Use of Galileo's telescope by an non-professional astronomer : A non-professional astronomer uses this telescope, normally adapted for the observation of terrestrial objects, for observing two lunar craters : Copernicus (diameter : 96 km) and Clavius (diameter : 240 km).
Can the astronomer see these two lunar craters : with the naked eye? with this telescope? Justify your answers.

Reminders :

- Earth-Moon distance : $D_{EM} = 384\,000$ km.
- The eye angular resolution (characterized by the minimum angle above which it is possible to distinguish two points) is 3×10^{-4} rad.

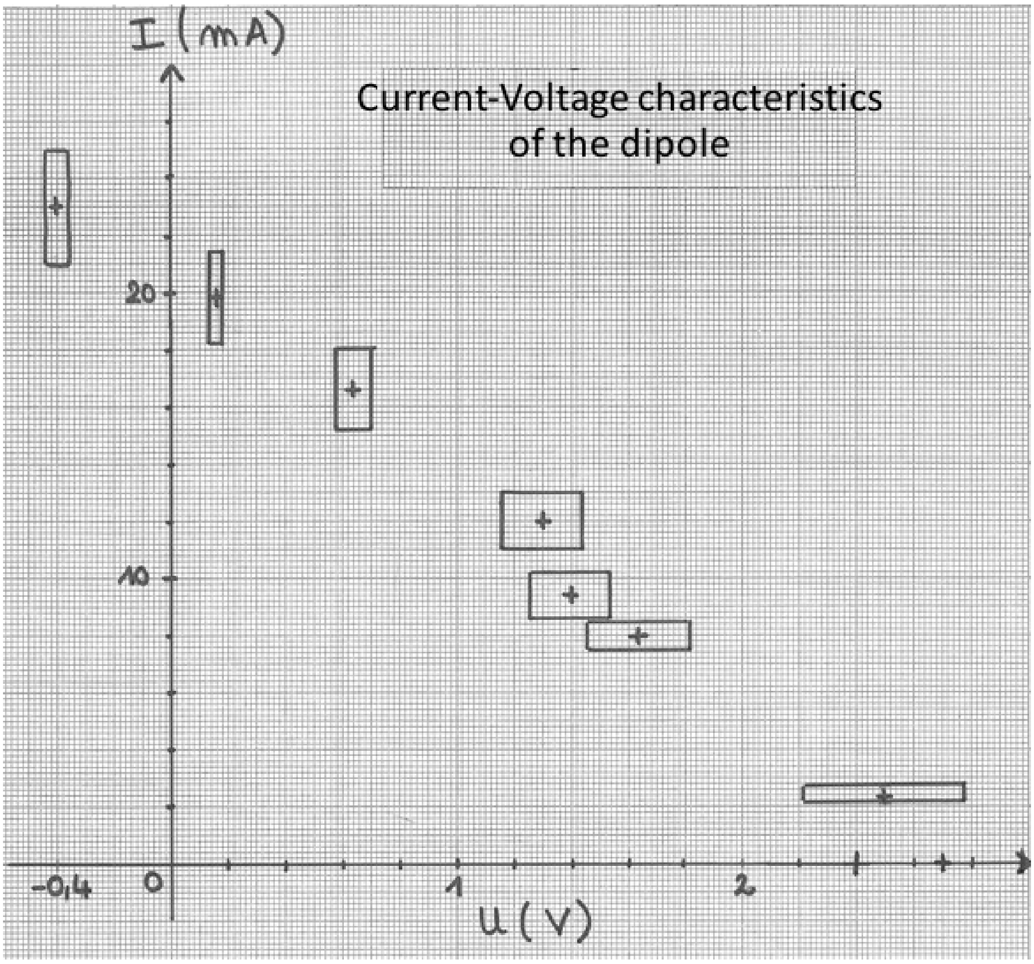
Exercise 3 : Autocollimation (6 points)

Consider an object AB, a thin converging lens L and a plane mirror M whose normal direction is parallel to the optical axis of L (see **document 3**). The focal distance of L is 2 cm and AB length is 1 cm. AB is placed 3 cm in front of L in **case a** and 2 cm in front of L in **case b**.
Let A_1B_1 be the image of AB formed by the lens L, A_2B_2 is the image formed by the mirror M from A_1B_1 and finally $A'B'$ is the final image of A_2B_2 formed by L.
Note : The transverse magnification γ of a mirror is constant and equals 1.

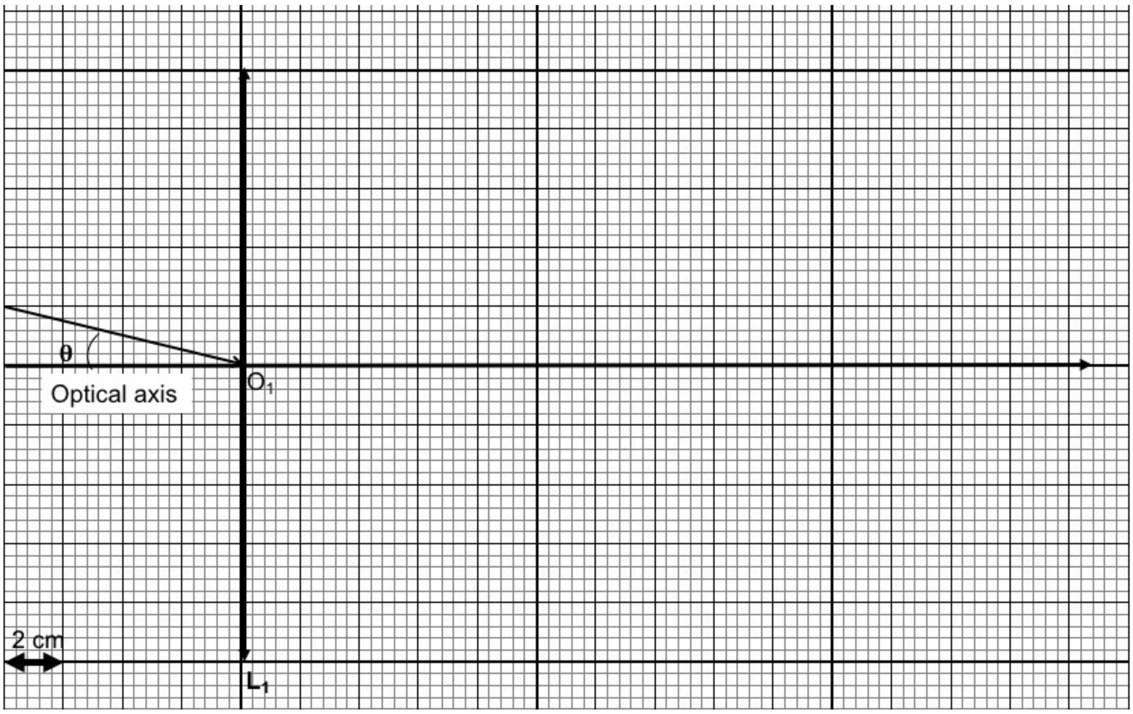
1. For each case (**a and b**), trace on **document 3** the ray path of at least two rays issued from point B in order to construct successively the images A_1B_1, A_2B_2 and $A'B'$.
2. We would like to determine results of **case a** by calculations :
2. 1 By calculations, determine the position and length of A_1B_1 (for case a)
2. 2 By calculations, determine the position and length of A_2B_2 (for case a)
2. 3 Bonus : By calculations, determine the position and length of $A'B'$ (for case a)
3. From the situation depicted in **case b**, what would happen if one would move the mirror, while keeping its normal parallel to the optical axis of the lens?
4. Propose an experimental method to determine the focal length of a thin converging lens using a plane mirror. Describe briefly your protocol.

Document 1 :

NAME and GROUP :



Document 2 :



Document 3 :