PHYSICS EXAM - Year: 2014-2015

ELECTRODYNAMICS

Duration: 2 h 00

- No documents allowed. The use of not-programmable calculator is allowed.

- The marks will account for the justifications, the critical analysis of your results, as well as for the writing and the general clarity and cleanness of your documents.

- The conventions and the physical quantities of interest will always have to be defined and specified on your schemes.

TWO SEPARATED DOCUMENTS ARE REQUIRED FOR THE OPTICS AND THE ELECTRODYNAMICS ASSIGNEMENTS.

Assignment 1: Optics

An experimental set-up is composed of a light source, an object, a thin lens (L_1) and a screen (see Figure 1).

1). A sharp image of the object AB is formed on the screen.

a. Give the literal expression of the magnification γ.
b. Give the literal expression of the focal length f_1'.
c. Compute the values of γ and f_1' if d = 1 m.

2). A second thin lens, L_2, of focal length f_2' = -50 cm, is placed after the lens L_1. The distance $\overline{O_1A}$ remains unchanged, equal to 1 m. The aim is to obtain a total magnification of -5, from the object AB to the final image through L_2.

a. Determine the distance $\overline{O_1O_2}$.
b. Where should the screen be placed to get a sharp image?
c. Check your results with a ray-diagram.

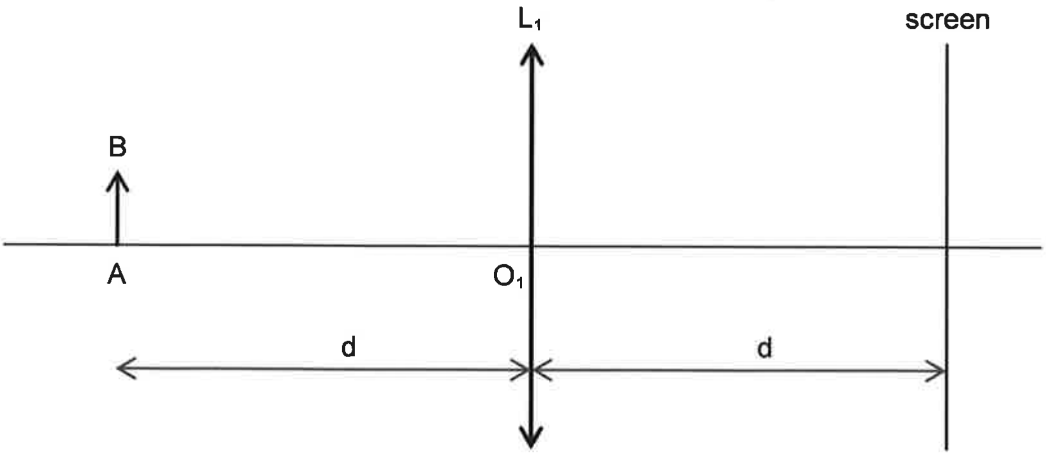

Figure 1 : Experimental set-up.

Assignment 2: Optimal charge for the photovoltaic conversion

A solar cell is a dipole which converts solar energy into electrical energy (DC). Thus the energy efficiency is defined by:

$$\eta = \text{energy efficiency} = \frac{\text{Output electrical supplied power}}{\text{Input solar power}} \quad \textbf{(eq. 1)}$$

Focusing on its electrical characteristics, its ideal I.V. curve, which depends on lighting conditions, can be determined. It is given in figure 2 for two weather conditions (sunny and cloudy) corresponding to solar density power equal to 100±5 W/m² and 75±3 W/m² respectively (*NB: the solar cell surface is 800 mm²*).

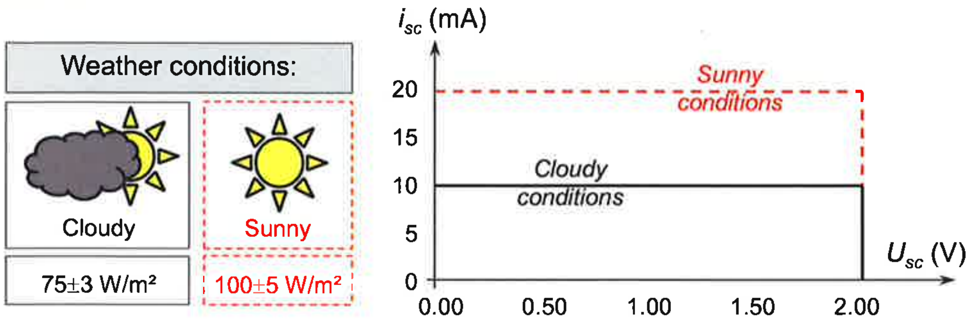

Figure 2 :

Modeled I-V curves for a solar cell under 2 sunlight conditions (sunny and cloudy) in active sign convention (ASC).

1). Provide the expression for the electrical power supplied by the solar cell. Is it constant for a given sunlight condition (justify)?

2). Calculate the maximum energy efficiency for both sunlight conditions (you will assume that the uncertainties on i_{sc} and U_{sc} are negligible).

3). A resistor (R_1 = 200 Ω) is now connected in series with the solar cell as displayed in figure 3a. For **sunny conditions only** and using the I.V. curve in figure 2, determine the energy efficiency of the solar cell (again, you will assume that the uncertainties on i_{sc} and U_{sc} are negligible).

4). A variable resistor is now connected in parallel with R_1 (see figure 3b). For **sunny conditions only** and using the I.V. curve in figure 2, determine the needed value of the variable resistance R to maximize the energy efficiency.

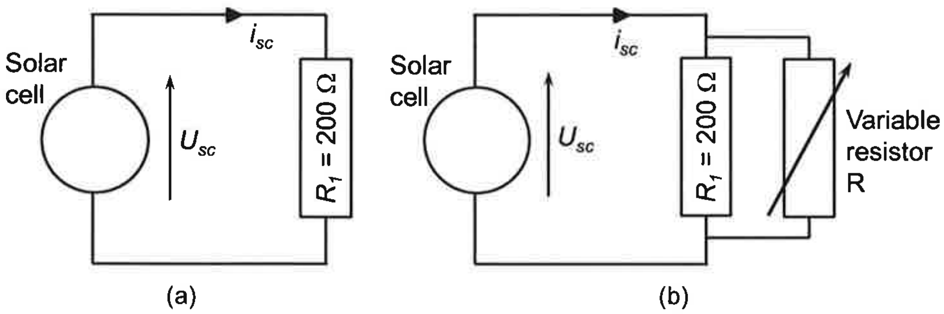

Figure 3 :

Photovoltaic cell serving as a generator.
(a) initial configuration,
(b) optimized configuration.

5). BONUS question - Equivalent dipoles **for a given sunlight condition**:

a. Assuming that the operating point of the solar cell belongs to the vertical part of its I.V. curve, by which equivalent dipole could the solar cell be replaced?
b. Same question, now assuming that the operating point of the solar cell belongs to the horizontal part of its I.V. curve.

Assignment 3: RLC Filter

Let us consider an ideal AC generator supplying a circuit comprising a resistor of resistance R, a capacitor of capacitance C and an ideal coil of inductance L (see Figure 4). The generator delivers a sinusoidal voltage $u_g(t)$ of angular frequency ω and of RMS value U_g. We will note $i(t)$ the current intensity in the circuit (see Figure 4).

If we consider the voltage at the terminals of the resistor (denoted $u_R(t)$ in Figure 4) as the output voltage and $u_g(t)$ as the input voltage, this RLC series circuit constitutes a filter. The aim of this assignment is to study this filter and the influence of the dipoles characteristics on its behavior.

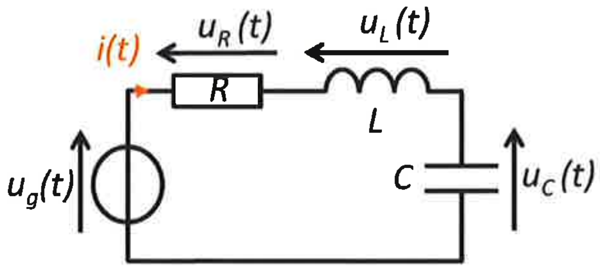

Figure 4 :
RLC series circuit.

1). $U_R(t)$ being the output voltage and $u_g(t)$ the input voltage, determine the nature of the filter thanks to equivalent schemes at very high and very low frequencies.

2). Scheme (and explain) the circuit you would set-up to determine the Bode magnitude plot for this filter using an oscilloscope.

3). Express the complex transfer function for this filter.

4). **With RC = L/R** draw the **asymptotical** Bode magnitude plot (G_{dB} vs ω). Justify and figure on your diagram all its key characteristics (maximum gain, ω_0 ...).

NB: the angular frequency corresponding to the maximum gain will be denoted ω_0.

5). Recall the definition of a cut-off angular frequency. Using the asymptotical Bode diagram you previously drew, show that there are two cut-off angular frequencies for this filter, denoted ω_{c1} and $\omega_{c2} > \omega_{c1}$ and figure them on the diagram.

6). It would be possible to show that:

$$(\omega_{c2} - \omega_{c1}) = R / L \qquad \textbf{(eq. 2)}$$

Explain the physical meaning of $(\omega_{c2} - \omega_{c1})$.

7). Q, so-called the **"Quality factor"** of the filter, is defined as follow:

$$Q = L\,\omega_0 / R \qquad \textbf{(eq. 3)}$$

Justify this designation. What is the dimension of Q?

8). For this question, $L = 1$ µH.

The FM radios are broadcasted on 100-kHz-wide channels around a "carrier" frequency between 87.5 MHz and 108 MHz.

In Lyon, how could we use the previous set up, and which values should be chosen for the R and C components, in order to be able to listen to *"Radio Scoop"* (carrier frequency 92.0 MHz) without interferences with *"Radio pluriel"* (carrier frequency 91.5 MHz) or *"France musique"* (carrier frequency 92.4 MHz)?