Exam #2 – Physics

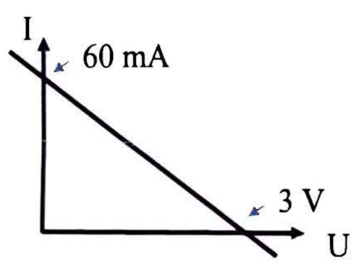
Friday, November 17, 2017 **Duration: 1 h 30**

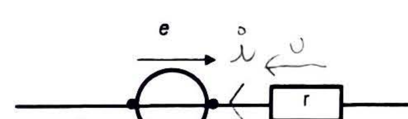
No documents allowed. No mobile phone. The use of not-programmable calculator is allowed. Indicative grading scale.

The marks will account not only for the results, but also for the justifications, and the way you analyze the results. Before any numerical application, the literal expression should be given. It is also reminded that the general clarity and cleanness of your paper may also be taken into account.

Lecture questions (≈ 2 points)

Let consider a real voltage source, which I-V curve is given below with active sign convention.





1) Copy the scheme of the voltage source on your exam sheet and indicate the convention used for U and I.
2) Give the values of e and r.

Exercise 1 – Uncertainties, dimensions, units (≈ 8 points)

An INSA graduate buys a renovated house. Only one wall does not have any insulation. The thickness of this wall is 40 cm (measurement accuracy 1 cm). Its thermal conductivity $\lambda_p = 1.00\ W.m^{-1}.K^{-1}$ is known with a relative uncertainty of 10%.

Question 1

The buyer measures the dimensions of the wall with his measuring tape (length 2 m; graduated in cm). He finds a height $h = 2.87\ m$ and a length $L = 7.12\ m$.

a) List the possible sources of uncertainty on the measurements.
b) Estimate the uncertainties on h and L.
c) Deduce the uncertainty on the wall area A.

Question 2

The thermal power lost through the wall when both sides have different temperatures is given by $P = \frac{\Delta\theta}{R}$ where $\Delta\theta$ is the temperature gradient and R the thermal resistance of the wall.

a) Express the dimension of R.
b) In the case of a parallelepiped object, R can also be expressed as $R = \frac{e}{\lambda A}$ with e the object thickness, A its area and λ its thermal conductivity. Determine the thermal resistance of the wall with its uncertainty. The result will be expressed as $R = (\dots \pm \cdots)\ unit$.
c) The "foot-pound force" is a unit of energy in the Engineering and Gravitational Systems in United States customary and imperial units of measures (source: Wikipedia). Give the value of R in this system of units, which allows the following units as base units: pound ($1\ lb = 453.6\ g$), foot ($1\ ft = 0.3048\ m$), minute, Kelvin. You do not have to compute the value of the uncertainty.

Question 3

The buyer wants to estimate the cost associated to the lack of insulation on this wall. He knows that the cost corresponding to a power of 1 kWh is $x = 0.15\ €/kWh$. $1\ Wh$ is the energy corresponding to a power of 1 Watt lost during 1 hour.

a) Give the literal expression of the total cost corresponding to the energy losses during a whole day. Is your expression homogeneous? Justify your answer.
b) Numerical application: give the value of the cost for one whole day, if the buyer wants to keep a temperature of 18°C inside the house when the external temperature is equal to 6°C. You do not have to compute the value of the uncertainty.

Exercise 2 – Optics: field view of an eyepiece (≈ 8 points)

We consider an eyepiece, composed of two thin lenses L_1 and L_2 used under paraxial approximation. The objective lens L_1 has a focal length of $f'_1 = 20\ cm$ and the ocular L_2 has a focal length of $f'_2 = 15\ cm$.

In this exercise, we consider that the eyepiece has been set so that the observer can see a sharp image of an **object AB located at a finite distance** (see scheme 1) **without any accommodation**. The object is placed at 60 cm before L_1. The lenses have small diameters but on scheme 1, the small diameter has not been taken into account so that you can trace the paths of all the rays.

Question 1

a) Where should the intermediate image $A'_1B'_1$ (image of the object AB through the objective lens L_1) be placed so that the observer can see a sharp image **without any accommodation**?
b) Deduce the literal expression, and then give the value of the distance $H = O_1O_2$ (distance between both lenses) once the observer sees a sharp image without any accommodation.
c) Draw on scheme 1 the **complete** path of three specific rays coming from B to the eye: the ray passing to the optical center O_1 of the objective lens, and two rays passing at the edges of the objective lens L_1.
d) Is the final image $A'B'$ reversed or upright? Explain your answer.

Question 2

In this question, we will take into account the fact that the lenses L_1 and L_2 are placed in a plastic tube of diameter $d = 2\ cm$. The tube is not transparent.

a) Correct scheme 1 by indicating the real dimension of the lenses and the presence of the tube (you do not need to trace/change the path of any ray). Explain why it is not possible to see point B.

b) Among all the points of the object AB that can be seen by the observer, C is the farthest one to the optical axis. Where is point C_1, image of C through the objective lens L_1? Place C and C_1 on scheme 1.

c) With the help of your ray-diagram, determine the literal expression of AC as a function of O_1A_1', O_1A and d.

Question 3

In fact, point C is visible but one ray only goes out of the tube. The final image C' is thus not very bright.

a) Trace the path of the ray shown in scheme 2 before it arrives in the tube. You will call D the point belonging to the object AB from which this ray comes.

b) Trace the **complete** path of the ray DE.

Bonus: for a uniformly illuminated object AC, comment the brightness of the image seen by the observer through the eyepiece.