

**Physics Exam 1**  
**Friday November 15, 2024 - Duration : 1h30**

*Not only will your results be evaluated, but more importantly, your ability to clearly justify them and critically analyze them afterwards will also be assessed. Additionally, every result must be presented in a literal form using only the data provided in the statement. It is also emphasized to pay attention to spelling and presentation quality.*

*No reference materials are allowed. Calculators in exam mode are permitted. The grading scale is provided for guidance only.*

**Any numerical result given without a unit and any non-homogeneous literal expression will have no value.**

**The three exercises are independent.**

**Exercise 1 : Fluid Flow (5 points)**

We consider a fluid flowing between two plates separated by a distance  $e$ . To maintain the fluid flow at a velocity  $v$ , a force  $F$  per unit surface area  $A$  must be applied such that :  $\frac{F}{A} = \eta \frac{v}{e}$ , where  $\eta$  is the viscosity of the fluid.

1. Determine the dimension of the viscosity  $\eta$ .
2. Express the viscosity in the (cm, gram, second) system for a viscosity of 0.018 in SI units.

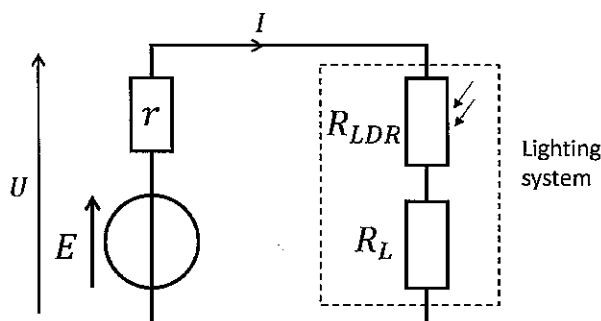
The flow rate  $D$  of a fluid through a capillary is given as a function of the pressure difference  $\Delta P$  (SI unit : Pascal, Pa), its length  $L$  and its radius  $r$  :  $D = \frac{\pi \Delta P r^4}{8 \eta L}$ .

3. Determine the dimension of the flow rate  $D$ . Is it a mass flow rate or a volumetric flow rate?
4. Given  $\Delta P = 4.0 \pm 0.1$  kPa,  $r = 5.0 \pm 0.5$  mm,  $\eta = 0.018 \pm 0.003$  USI and  $L = 50.0 \pm 0.1$  cm. calculate the flow rate and its uncertainty.

**Exercise 2 : Analyzing a Lighting System with a Photoresistance (9 points)**

In a new library project at INSA, a lighting system adjusts the light intensity based on ambient brightness using a photoresistance (LDR : Light Dependent Resistor). The goal is to determine the operating point of the circuit while accounting for measurement uncertainties.

In this circuit, the lamp is modeled as a resistor  $R_L = 100 \Omega$  known within a 2% uncertainty. The photoresistance has a non-linear curve representing the variation of its resistance  $R_{LDR}$  as a function of the ambient illumination  $L$  (figure 1). The circuit is powered by a DC voltage  $E = 12$  V with an internal resistance  $r = 4 \Omega$ .



1. Use the graph in figure 1 to determine the values of  $R_{LDR}$  at  $L_1 = 100$  lux,  $L_2 = 300$  lux, et  $L_3 = 500$  lux along with their uncertainties.
2. For each of the three illumination values, calculate the resistance of the lighting system with its uncertainty and plot the characteristic  $I(U)$  curve for each on the provided graph paper (without uncertainties).
3. Find the corresponding operating points  $(I_1, U_1)$ ,  $(I_2, U_2)$  and  $(I_3, U_3)$  by plotting the generator's characteristic  $I(U)$  curve on the same graph.

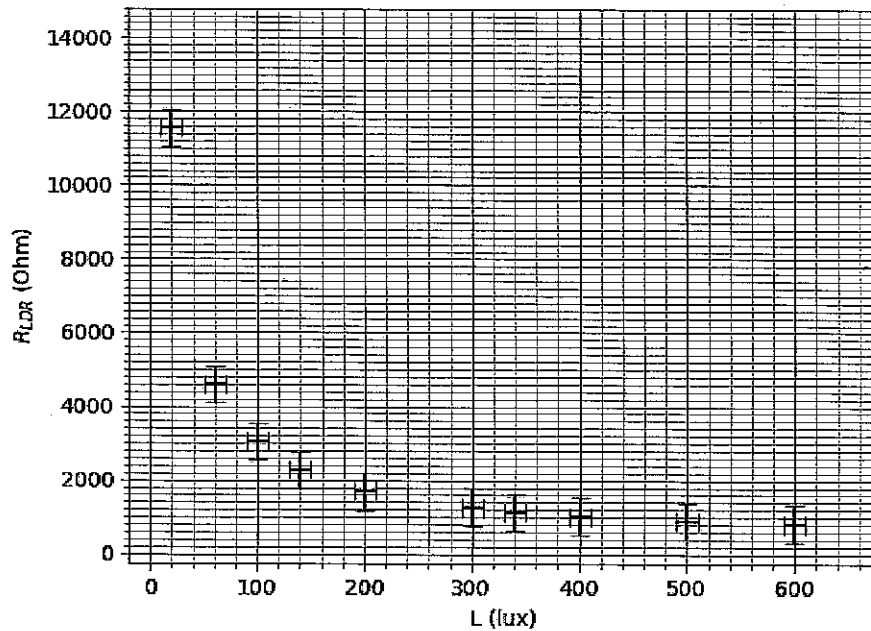


FIGURE 1 – Variation of the photoresistance vs illumination

- For the  $I(U)$  plot of  $R_{LDR}$  at 100 lux, draw the lines of minimum and maximum slopes. What is the uncertainty of the operating point for this  $R_{LDR}$  value?
- For  $L_1 = 100$  lux, calculate the power dissipated by the lighting system and its uncertainty.

### **Exercise 3 : Open Problem : A Surveillance Drone (6 points)**

INSA aims to design a surveillance drone. You need to estimate the maximum range the drone can achieve before exhausting its battery. The drone is powered by a battery with an energy capacity of  $E_b = 500$  Wh and flies at a constant speed  $v$ .

Using dimensional analysis, realistic orders of magnitude, and simplifying assumptions, you are tasked with establishing a relationship between the drone's speed and the distance it can travel. You must also account for the drone motor's efficiency.

*Hints :*

- The power required to keep the drone flying depends on its speed and aerodynamic properties. It includes two terms : a constant term estimated at 100 W , and a term that depends only on the drone's mass, length, and speed.
- The drone's electric motor efficiency is  $\eta = 80$  %.

**Estimate the drone's maximum range, explaining your assumptions and reasoning at each step. Ensure unit consistency is verified.**