IE1-S1 - Physics - Correction

Name : **First Name :** **Group :**

Exercise 1 : Fluid flow (4 points)	4 / pts
1. We have : $\dim(F) = M.L.T^{-2}$	0.25
$\dim(S) = L^2$, $\dim(v) = L.T^{-1}$, $\dim(e) = L$	0.25
$\eta = \frac{F}{S}\frac{e}{v} \Rightarrow \dim(\eta) = M.L^{-1}.T^{-1}$	0.5
2. $\eta = 0.018$ kg.m^{-1}.s^{-1}	0.25
$\eta = 0.018$ kg.m^{-1}.s^{-1} $= 0.018 \times (1000g) \times (100cm)^{-1} = 0.18$ g.cm^{-1}.s^{-1}	0.5
3. We have : $\dim(\Delta P) = M.L^{-1}.T^{-2}$	0.25
$\dim(D) = \frac{\dim(P).L^4}{\dim(\eta).L} = L^3.T^{-1}$	0.5
It is thus a volume flow rate (volume per unit time)	0.5
4. Bounding : $D_{min} = 5.969 \times 10^{-5}$ m^3.s^{-1}, $D_{max} = 1.968 \times 10^{-4}$ m^3.s^{-1} $\Rightarrow$ $\boxed{D = (1.3 \pm 0.7) \times 10^{-4} \text{ m}^3.\text{s}^{-1}}$ *Differential method (also accepted)* $\frac{\Delta(D)}{D} = \frac{\Delta(\Delta P)}{\Delta P} + 4\frac{\Delta r}{r} + \frac{\Delta\eta}{\eta} + \frac{\Delta L}{L} = 0.594$, $D = \frac{\pi \Delta P r^4}{8\eta L} = 1.091 \times 10^{-4}$ m^3.s^{-1} $\Rightarrow D = (1.1 \pm 0.7) \times 10^{-4}$ m^3.s^{-1}	1 *(or 0, no intermediate points)*

Exercise 2 : Analysis of a lighting system with a photoresistor (10 points + 1 bonus)	10+1/ pts
1. **Photoresistor and uncertainty :** From the graph, we read the minimum and maximum resistances for each light intensity value to deduce the value of R_{LDR} and its uncertainty :	1.5

L (lux)	R_{LDR}^{min} ($k\Omega$)	R_{LDR}^{max} ($k\Omega$)	R_{LDR} ($k\Omega$)
100	2.6	3.6	(3.1 ± 0.5)
300	0.8	1.8	(1.3 ± 0.5)
500	0.4	1.4	(0.9 ± 0.5)

2. **Resistance of the lighting system and uncertainties :**

The lighting system is composed of the resistance of the lamp ($R_L = (100 \pm 2)\,\Omega$) in series with the photoresistor (R_{LDR}). Its total resistance is therefore :

$$R_{tot} = R_L + R_{LDR}$$

We calculate the minimum (resp. maximum) value of the lighting system resistance based on the extreme values of R_L and R_{LDR} :

$$R_{tot}^{min} = R_L^{min} + R_{LDR}^{min} \quad \text{and} \quad R_{tot}^{max} = R_L^{max} + R_{LDR}^{max}$$

The table below details calculations for each light intensity.

Note : The minimum/maximum values of R_{tot}, the average value (R_{tot}^{avg}), and the uncertainty (ΔR_{tot}) are indicative only and have been arbitrarily truncated after the 3rd decimal. Only the final value (last column) rounded to the nearest 0.1 kilo-ohm is considered.

1.5pts (0.5 per value)

L (lux)	$R_{tot}^{min}\,(k\Omega)$	$R_{tot}^{max}\,(k\Omega)$	$R_{tot}^{avg}\,(k\Omega)$	$\Delta R_{tot}\,(k\Omega)$	$R_{tot}\,(k\Omega)$
100	$\approx 2.698\ldots$	$\approx 3.702\ldots$	$\approx 3.200\ldots$	$\approx 0.502\ldots$	(3.2 ± 0.6)
300	$\approx 0.898\ldots$	$\approx 1.902\ldots$	$\approx 1.400\ldots$	$\approx 0.502\ldots$	(1.4 ± 0.6)
500	$\approx 0.498\ldots$	$\approx .502\ldots$	$\approx 1.000\ldots$	$\approx 0.502\ldots$	(1.0 ± 0.6)

Graph plotting :
For plotting the graphs, knowing that they necessarily pass through the origin, we might calculate the current for the maximum voltage (*i.e.,* 12 V) rounded to the nearest 0.05 milliampere (the smallest division on the graph) :

L (lux)	$R_{tot}\,(k\Omega)$	Current at $12\,V\,(mA)$
100	3.2	$3.75 \approx 3.75$
300	1.4	$8.57 \approx 8.55$
500	1.0	$12.00 \approx 12.00$

Note : From the previous values, we observe that the resistance characteristics at 300 and 500 lux at 12 V *fall outside the graph. Therefore, we calculate the voltage value that allows reaching the maximum current of* 8 mA *on the graph, rounded to the nearest* 0.05 *V. We find* 11.20 V *and* 8.00 V, *respectively (300 and 500 lux).*
See graph on last page

1.5pts (0.5 per curve)

3. **Operating points :**
To determine the operating points, we add the characteristic line of the generator. According to the conventions of the diagram :

$$U = E - r\,I \quad \text{or} \quad I = \frac{E-U}{r}$$

This line intersects the horizontal axis ($I = 0$) at $U = E = 12\,V$.

*For the other point, we cannot use the intersection with the vertical axis as it lies outside the graph (I =*300 mA *at* $U = 0\,V$*). We thus calculate the voltage U where the current reaches the maximum accessible value (i.e.,* 8 mA*), rounding it to the nearest graph division (*0.05 V*) : we obtain (*11.965 V≈12.00 V,8 mA*). The I-U curve of the generator is vertical for the chosen graph scale!*

1.0pt (generator curve).

The three operating points are noted as $P_1 = (U_1, I_1)$, $P_2 = (U_2, I_2)$, and $P_3 = (U_3, I_3)$ (from 100 to 500 lux).
We note that the operating point at 100 lux is the only one readable from the graph
From the graph, we read the following values (rounded to 0.05 V/ 1 mA) :

L (lux)	$U\,(V)$	I (mA)
100	12.0	3.75
300	12.0	8.57
500	12.0	*out of range*

1.5pt

4. **Considering uncertainties for L=100 lux :**
Using the same method as before, we determine the points of the characteristic at $12\,V$ for the extreme values of R_{LDR} at 100 lux :
We obtain $(12\,V, 4.61\,mA)$ and $(12\,V, 3.16\,mA)$ for 2.6 kΩ and 3.8 kΩ, allowing the plotting of curves (dashed lines).

1.0pt (0.5pt per plot)

We find the two extreme operating points, noted as P_1^{min} and P_1^{max} :
$P_{1,min} = (12.0\,V, 3.16\,mA)$ and $P_{1,max} = (12.0\,V, 4.61\,mA)$.

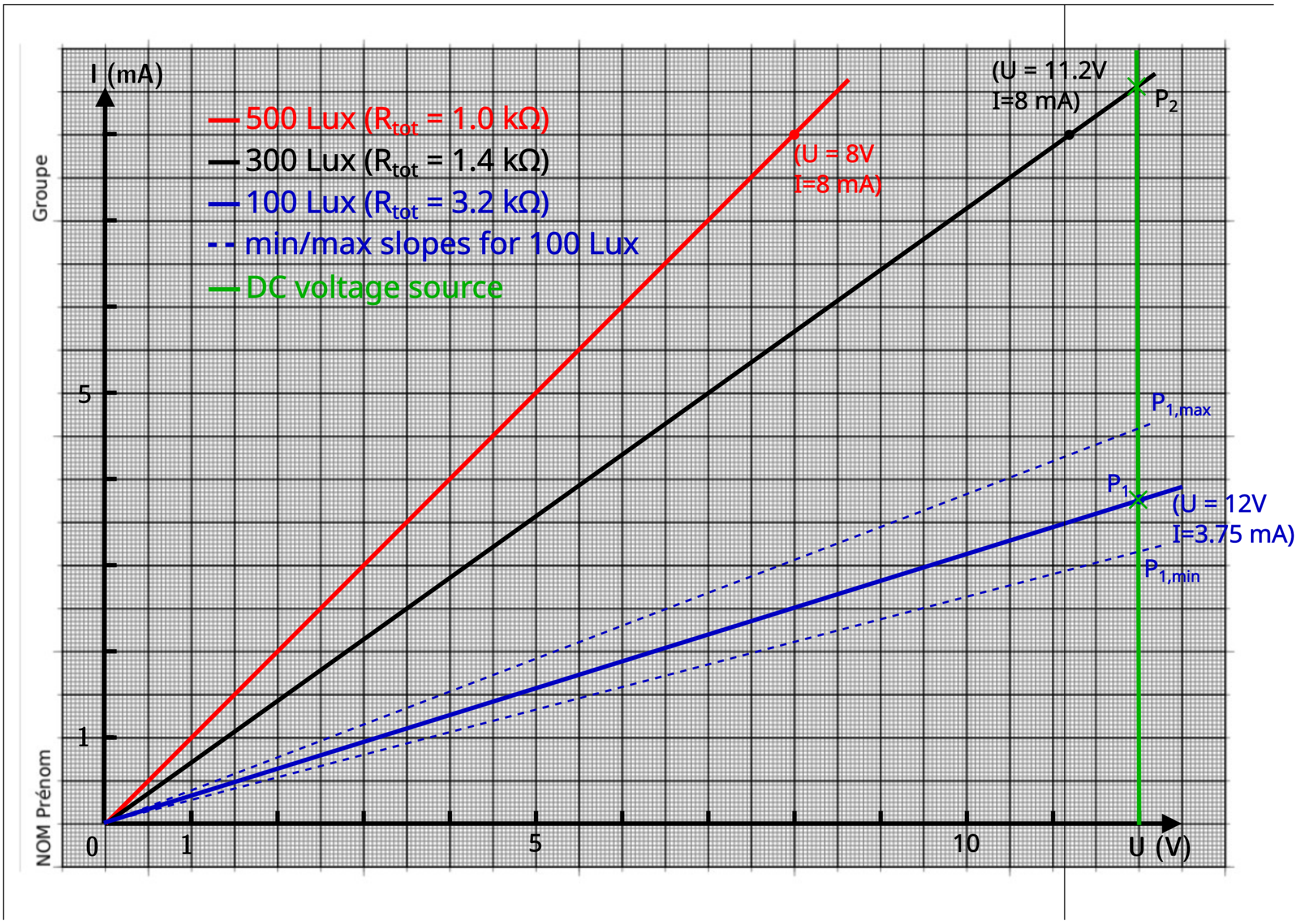
Considering these values and applying the bracketing method, we obtain the following uncertainties for the operating point at 100 lux :
$P_{100lux} = ((12.00 \pm 0.01)\,V; (3.89 \pm 0.73)\,mA)$

1.0pt (operating points + uncertainties)

One can question the relevance of the voltage uncertainty (smaller than the smallest graph division!), given possible reading errors or the precision of the plot. This is less critical for current values, which can be more accurately distinguished. To account for this, add at least one division to the final uncertainty (precision of plot and reading) : $P_{100lux} = ((12.00 \pm 0.05)\,V; (3.89 \pm 0.73)\,mA)$	+0.5pt bonus for accounting for plot and reading uncertainties
5. **Power dissipation at 100 lux and uncertainty :** With the operating point, we know the voltage across the lighting system and the current flowing through it. We calculate the product $P = U \cdot I$ (using the receiver convention...) with the operating point We get : $P_{min} = U_{max} \cdot I_{min} \approx 37.92\,mW$ $P_{max} = U_{min} \cdot I_{max} \approx 55.32\,mW$ hence $P = (46.62 \pm 8.70)\,mW$	1.0 pt

Exercise 3 : Open problem : drone (6.5 points)	6.5 / pts
Problem self-appropriation : In order to determine the distance travelled at constant speed (according to text), we need to find the **time of flight**. We know the total available energy, we thus need to determine the consumed power in order to estimate the time of flight. We want the **maximal distance**, we thus need to determine which parameters play a role on the distance and maximize it. Fixed parameters are the available energy, the drone mass and length, the variable one is its flight speed. Only the velocity can be change to maximize the distance. Definition of physical quantities : • m the drone mass, ℓ its length (to estimate) • P the consumed power during the flight, with $P = P_0 + P_1$, $P_0 = 100$ W the constant part and P_1 the variable part, function of m, ℓ and v (the drone speed) • T the time of flight and $D = v\ T$ the distance travelled • $E_b = 500$ Wh (given) and $\eta = 80\%$ the motor efficiency	1.5

Build a methodology to solve a problem (analyze) : We first need the expression of P_1. For that we can rely on dimensional analysis, since we know that $P_1 = f(m, \ell, v)$ We will then estimate T so that $P \times T = \eta E_b$ and finally D using $$D = vT = v\frac{\eta E_b}{P}$$ **Hypothesis** : • constant flight speed (given by the text) : we neglect the influence of take off, acceleration, deceleration and landing on energy consumption. This assumption is justified if the flight duration is long compared to these phases. • the dimensionless coefficient in P_1 will be considered to be equal to 1, which can be a strong limitation	1
Use the methodology : Dimensional analysis : we set $P_1 = \alpha m^a \ell^b v^c$. $\dim(P_1) = M\,L^2\,T^{-3} = [\dim(m)]^a\,[\dim(\ell)]^b\,[\dim(v)]^c = M^a L^{b+c} T^{-c}$ $$\begin{cases} a = 1 \\ b+c = 2 \\ -c = -3 \end{cases} \Rightarrow \begin{cases} a = 1 \\ b = -1 \\ c = 3 \end{cases} \Rightarrow P_1 = \frac{mv^3}{\ell}$$	0.5
(assuming $\alpha = 1$) We get $$T = \frac{\eta E_b}{P} = \frac{\eta E_b}{P_0 + mv^3/\ell}$$ and thus $$D = vT = \frac{\eta E_b}{P_0/v + mv^2/\ell}$$	0.5
The distance is maximal if the numerator is minimal, we are thus looking for a minimum of function $$f(v) = \frac{P_0}{v} + \frac{m}{\ell}v^2$$ $\frac{df}{dv} = 0$ gives an extremum for $v_0 = \left(\frac{\ell P_0}{2m}\right)^{1/3}$, which is indeed a minimum (one can look at the limites at 0 and $+\infty$)	0.5
The maximal distance the drone can travel is thus $$\boxed{D_{\max} = \frac{\eta E_b}{\frac{3}{2}\left(2P_0^2 m/\ell\right)^{1/3}}}$$	1
Taking $m = 2$ kg and $\ell = 30$ cm, we get $D_{\max} \approx 19$ km (18791 m)	0.5
Have a critical look one the results (validate) : Discussion on assumptions and orders of magnitude	0.5
Communicate : Evaluation of the overall clarity	0.5


I (mA)
500 Lux (R_{tot} = 1.0 kΩ)
300 Lux (R_{tot} = 1.4 kΩ)
100 Lux (R_{tot} = 3.2 kΩ)
- - min/max slopes for 100 Lux
DC voltage source
(U = 8V
I=8 mA)
(U = 11.2V
I=8 mA)
P_2
$P_{1,max}$
P_1
(U = 12V
I=3.75 mA)
$P_{1,min}$
Groupe
NOM Prénom
5
1
0
1
5
10
U (V)