Physics test 1 – SCAN – Correction

Exercise 1: Determination of a static friction coefficient – 13.5 points.		
Elements of correction, expected items and grading scale		
1. **Method 1: Measure of the critical angle.** (a) In order to determine $\tan(\alpha)$ one can use a right-angled triangle on the picture, and measure with a ruler the adjacent (noted b) and opposite (noted a) sides, and compute the ratio: $\frac{a}{b}$. Indeed, $\tan(\alpha) = \frac{a}{b}$. *Note that there is no need to have a scale*	Definition of the tangent. No confusion between "measure" and "compute". *Bonus: 0.5*	/1
(b) Uncertainty sources are: - Reading on the ruler ("man"), 2 times half a graduation: 1 mm - Ruler positioning on the picture (picture quality for determining the board extremities ("method"): 1 mm - Parallax issue when taking the picture ("method") : negligible.	1 pt for sources and 1 pt for the estimations.	/2
(c) According to figure 1, we get: - $a = (25 \pm 2)$ mm. - $b = (86 \pm 2)$ mm.	No point if no unit or incoherence between values and uncertainties.	/1

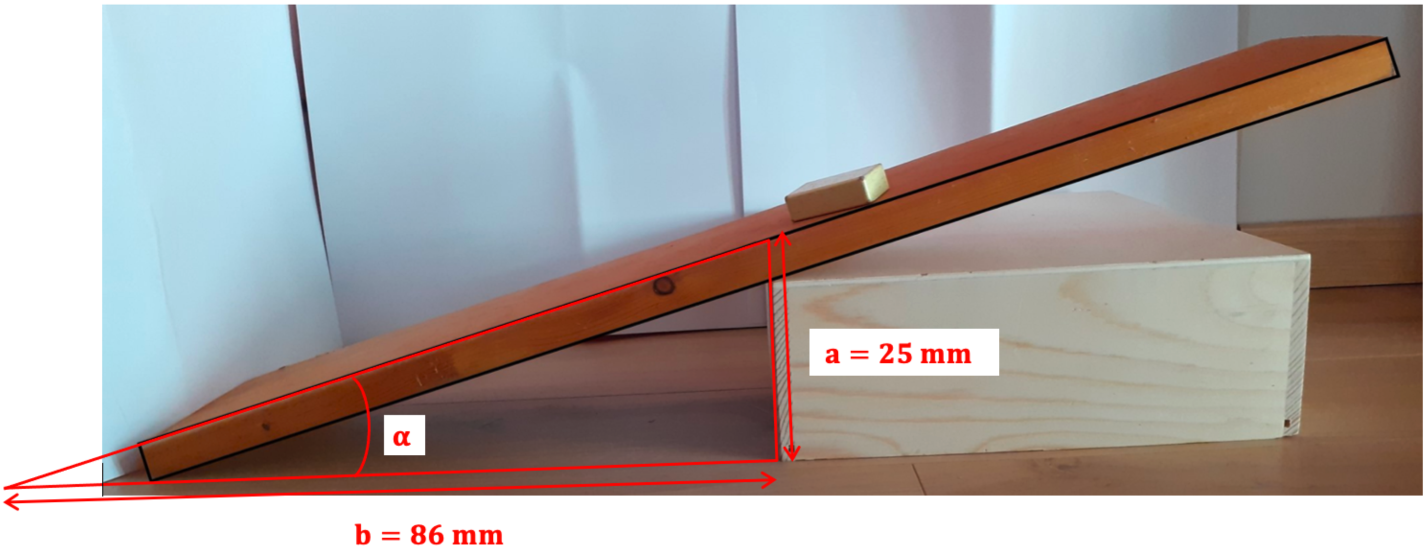

Figure 1: Method 1

(d) Determination of maximal $\mu_{s\ max}$ and minimal $\mu_{s\ min}$ values of static friction coefficient μ: - $\mu_{s\ max} = \frac{a_{max}}{b_{min}} = \frac{25+2}{86-2} \approx 0,3214$ - $\mu_{s\ min} = \frac{a_{min}}{b_{max}} = \frac{25-2}{86+2} \approx 0,2614$ Static friction coefficient and uncertainty: $$\mu_s = \frac{\mu_{s\ max}+\mu_{s\ min}}{2} \approx 0,2913 \text{ and : } \Delta\mu_s = \frac{\mu_{s\ max}-\mu_{s\ min}}{2} \approx 0,00300$$ The static friction coefficient is thus: $\mu_s = (0,29 \pm 0,03)$.	1 pt for $\mu_{s\ max}$ and $\mu_{s\ min}$, 1 pt for μ_s and $\Delta\mu_s$ and 0.5 pt for final result (No point if decimals are different or if final result is written with more than 2 digits (direct measures cannot have more digits).	/2.5
2. **Method 2: Change the mass of the tested body**. Using figure 2, we get the maximum $\mu_{s\ max}$ and minimum $\mu_{s\ min}$ values of the friction coefficient, which correspond respectively to the max and min slopes, since we have $m = \mu_s \times M$: - $\mu_{s\ max} = \frac{440}{1700} \approx 0,2588$ - $\mu_{s\ min} = \frac{520}{2100} \approx 0,2476$ Static friction coefficient and uncertainty: $$\mu_s = \frac{\mu_{s\ max}+\mu_{s\ min}}{2} \approx 0,2532 \text{ et : } \Delta\mu_s = \frac{\mu_{s\ max}-\mu_{s\ min}}{2} \approx 0,00560$$ The static friction coefficient is thus: $\mu_s = (0,25 \pm 0,01)$.	1 pt for each regression line (remove 0.5 pt if the line does no go through the origin). 1 pt for the determination of each slope. 1 pt for the value of μ_s and its uncertainty. 1 pt for the final result.	**/6**

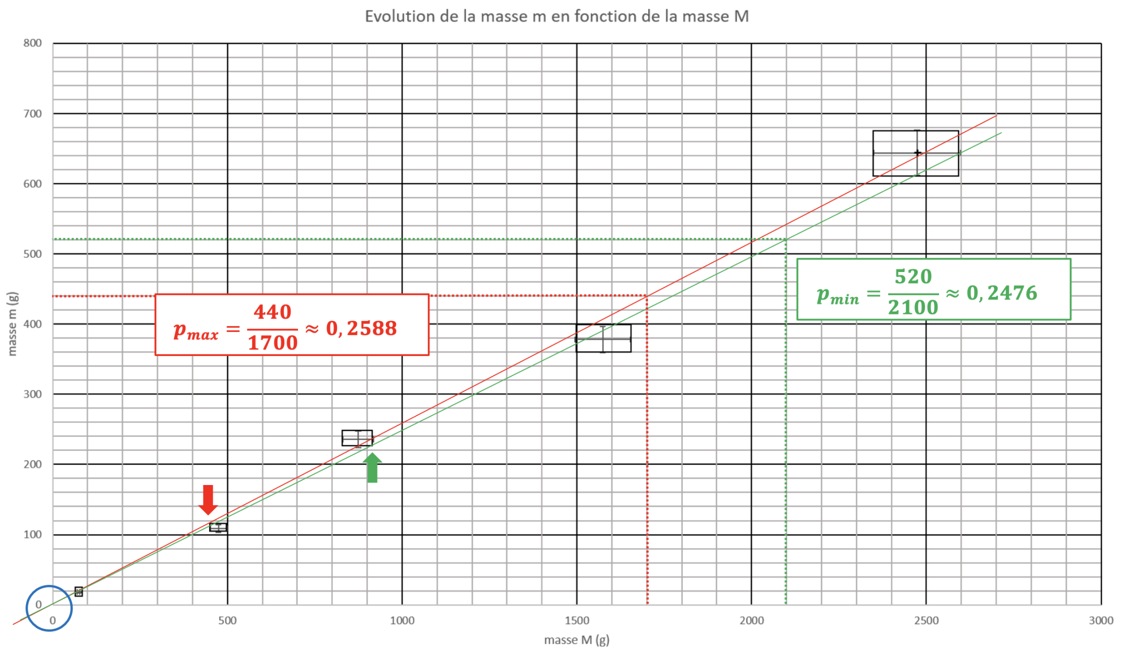

Figure 2: Method 2

3. **Comparison of the two methods**. With these measures, we see that the measured intervals do not intersect (see figure 3). We can estimate that method 2 should be more accurate, but longer.	0.5 pt for intervals comparison and 0.5 pt for any relevant remark.	/1

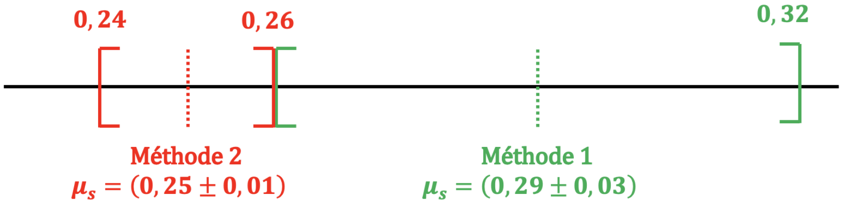

Figure 3: Measured intervals from the two methods

Exercise 2: Study of a wind turbine – 6.5 points		
Elements of correction, expected items and grading scale		
1. Total efficiency: $\eta_t = \frac{\text{Electric energy provided by the alternator}}{\text{Mechanical energy provided by the wind}}$	0.5	
Mechanical efficiency: $\eta_m = \frac{\text{Mechanical energy provided by the rotor}}{\text{Mechanical energy provided by the wind}}$	0.5	/1.5
Expected keywords: thermal dissipation/losses, friction (mechanical), Joule's effect	0.25 per relevant keyword, up to 0.5 pts	
2. **Electric power**. According to the text, one can write: $P = k\rho^\alpha\ v^\beta\ l^\gamma$, which gives $[P] = [k] \times \left[\rho^\alpha\right] \times \left[v^\beta\right] \times \left[l^\gamma\right]$. A power has the dimension of an energy per unit time: $[P] = \mathrm{ML^2T^{-3}}$. Moreover: $[k] = 1$; $\left[\rho\right] = \mathrm{ML^{-3}}$; $[v] = \mathrm{ML^{-1}}$ and $[l] = \mathrm{L}$. We get: $\mathrm{ML^2T^{-3}} = \mathrm{M}^\alpha\ \mathrm{L}^{-3\alpha}\mathrm{L}^\beta\ \mathrm{T}^{-\beta}\mathrm{L}^\gamma$,leading to the following equations with 3 unknowns: $\begin{cases} \alpha = 1 \\ -3\alpha+\beta+\gamma = 2 \\ -\beta = -3 \end{cases}$; $soit$: $\begin{cases} \alpha = 1 \\ \beta = 3 \\ \gamma = 2 \end{cases} \Leftrightarrow P = k\rho v^3 l^2$	0.5 pt for the dimension of a power. 0.5 pt for the dimension of a mass density. 0.5 pt for the dimensional equation. 1 pt for solving the equation and final writing.	/2.5
3. **Power conversion**. Mass conversion: $m = 550\ \mathrm{lb} \times \left(\frac{0.4536\ \mathrm{kg}}{1\ \mathrm{lb}}\right) = 249.48\ \mathrm{kg}$	0.5	
Velocity: $v = 1\ \mathrm{ft \cdot s^{-1}} = 0.3048\ \mathrm{m \cdot s^{-1}}$	0.25	
Power: 1 HP = 746 W	0.5	/2.5
Power in nominal working conditions: $P_{\mathrm{nom}} = 3\ \mathrm{MW} \times \left(\frac{1\ \mathrm{HP}}{746\ \mathrm{W}}\right) = 4.02 \times 10^3\ \mathrm{HP}$	1	
Result with 3 digits	0.25	