# Physics Exam 3
# Friday February 14, 2025 - 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.*

## Exercise 1 : Design of a tablet holder ($\approx 8$ pts.)

We are interested in the design of a tablet holder, whose schematic cross-sectional view is given in Figure 1.
The holder consists of a platform $BD = \ell$ connected at point $C$ to a leg that touches the ground at $A$. The leg $AC$ has a length denoted $h$, such that $ABC$ forms an equilateral triangle. A tablet of length $H$ is placed on the holder, starting from the ground at B. The tablet is assumed to be rigidly attached to $BD$ and cannot slide on it.

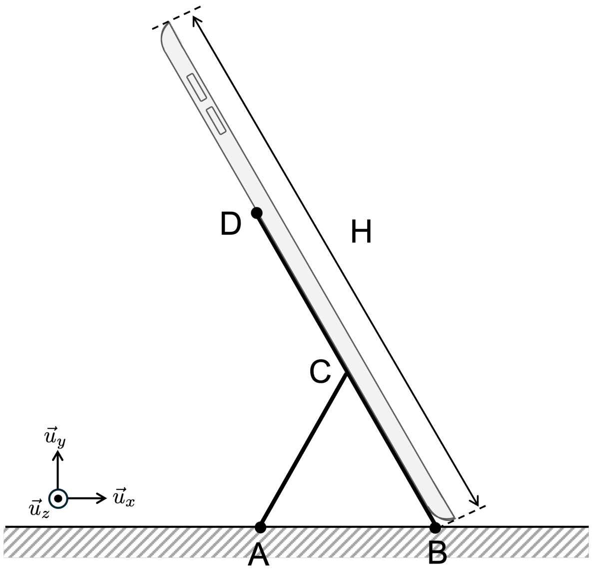



Figure 1 : Schematic view of a tablet holder.

In this exercise, we aim to determine the minimum length $h$ of the leg $AC$ required to prevent the tablet from flipping backward.

Both the tablet and the holder are considered homogeneous rigid bodies, negligible thickness, with respective masses $M$ and $m$. The weight of the leg $AC$ will be neglected and we will assume that the contact between the holder and ground (at points $A$ and $B$) is friction-less. Throughout this exercise we will use the Cartesian frame depicted in Fig. 1 with $\vec{u}_x$ horizontal rightwards and $\vec{u}_y$ vertical upwards.

<u>Numerical values :</u> $M$=480 g, $m$=125 g, $\ell$=20 cm, $H$=25 cm, $g$ =9.81 m s$^{-2}$ (gravitational acceleration)

1. Provide a detailed free body diagram of the {holder+tablet} system, *i.e.* illustrating all the mechanical actions at play on a scheme.
2. Determine $R_A$ and $R_B$ the norm of the reaction forces at $A$ and $B$.
3. What simple condition on $R_B$ would correspond to the tablet beginning to flip backward ? Deduce the minimal leg length $h_{min}$ and provide its numerical value. Comment.

We now add the effect of the user's finger on the tablet, modeled by a point force applied on $E$ so that $BE = \ell' = 22$ cm. The user force $\vec{F}_u$ is assumed to be perpendicular to the tablet.

4. Can the system be at equilibrium if the contacts with the ground remain friction-less? Justify your answer.

We consider now that there is friction **only on point** $B$, with a friction coefficient $\mu = 0.8$.

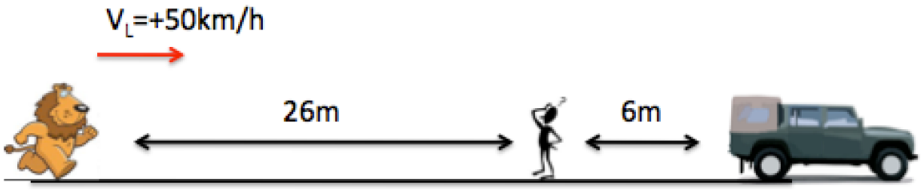
5. Assuming that the system {holder+tablet} is at equilibrium, determine the tangential component of the ground reaction force at $B$, and show that its normal component (along $\vec{u}_y$) can be expressed as

$$R_{B_N} = R_{B0} + \left(\frac{1}{2} - \frac{\ell'}{h}\right) \|\vec{F}_u\|$$

   with $R_{B0}$ the norm of the reaction force found at question 2 (in the absence of $\vec{F}_u$).

6. We consider in this question that $h = 11$ cm. If the user increases her/his force progressively, so that $\|\vec{F}_u\|$ starts from 0 and increases, how does the normal component of the force at point $B$ evolve? how does the tangential one evolve? Deduce if the tablet and its holder will first slide or tilt.
7. *BONUS :* Considering this limit for equilibrium, what is the new minimal leg length $h^{\star}_{min}$ so that the system remains at equilibrium under the user's action? Provide its numerical value with $\|\vec{F}_u\| = 1$ N and comment on the result.

## Exercise 2 : Jordan and the lion (≈ 5 pts.)




A lion starts at rest 26 m away from a clueless Jordan and charges towards him at a constant velocity of +50km/h. It takes Jordan 1 s to react to the lion, turn around and begin running at a velocity of +5 m/s towards his vehicle. Jordan's Land Rover is parked 6 m away from him and on the same axis as the lion's charge.

Will Jordan escape? If Jordan escapes, how far would the lion be from him as he reaches his car? If not, how far would Jordan be from his car?

## Exercise 3 : 2D motion (≈ 7 pts.)

A point $P$ is moving in the $Oxy$ plane, and its coordinates as a function of time are

$$x(t) = 20\alpha(t-\tau) \quad y(t) = \frac{10\alpha}{\tau}(t-\tau)^2,$$

with $\alpha = 1$ m.s$^{-1}$ and $\tau = 1$ s.

1. Find the equation of the trajectory $y(x)$ and draw it for t between 0 and 3s.
2. Determine the velocity and acceleration vectors in the cartesian frame.
3. Determine the tangent and normal vectors of the Tangent-Normal-Binormal frame (Frenet-Serret frame).
4. Deduce the tangential and normal components of the acceleration vector. What is the expression of the radius of curvature? Determiner its numerical value at $t = 1$ s and $t = 2$ s.
5. Describe the movement phases based on the evolution of $\vec{v}$ and $\vec{a}$.