Study of the handlebar of a gyropode

We are interested in the design of a Segway handle bar shown **Figure 1**. The inclination of the bar is used to indicate the direction and the rotational speed of the vehicle using a rotational sensor placed on the pivot connection 0 (**Figure 2**). This bar must be vertical and centered at rest without external force action.

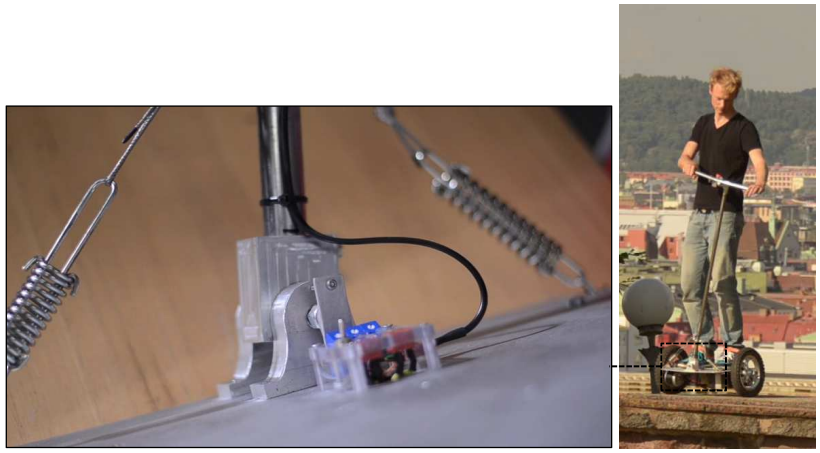

Figure n° 1 – Example of DIY Gyropode (http://p1r.se/robot/segway/)

First we consider the bar alone without spring as in **Figure 2a**.
For numerical applications: total bar length L = 1.2 m, mass of the bar M = 2 kg.

1. Provide the expression of the potential energy and deduct the equilibrium positions.
2. Which position of equilibrium is stable? Deduce an additional criterion in analysis of stable equilibrium positions.

We are now adding a torsion spring K_r (torque proportional to the angle) as shown in **Figure 2b**.

3. Give the expression of the potential energy and deduct if the stable equilibrium position are in the same positions.
4. What is the minimum value given to K_r to have an equilibrium point positioned in θ=0°.

It is easier to implement the return spring using tension springs as shown in **Figure 2c**. For the numerical application: distance 0A = 10 cm.

5. Repeat the previous study and propose a minimum stiffness $K_{l,mini}$ value for K_l.
6. Calculate the effort to apply for a travel-end bar of 5 cm if K_l=2.$K_{l,mini}$. For this, use the theorem of virtual work and the fundamental principle of statics.

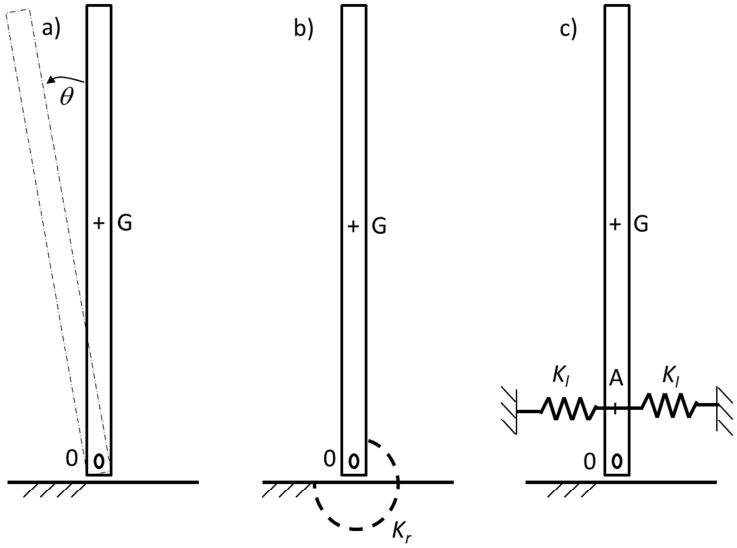

Figure n° 2 – Simplified geometries