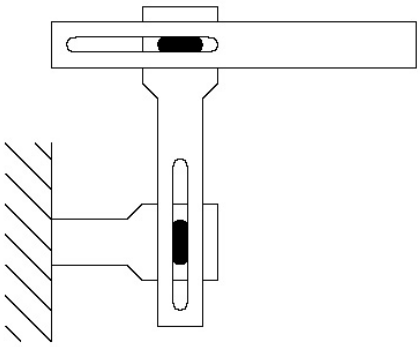
**Instituto Politécnico do Porto**
**Instituto Superior de Engenharia**
**Departamento de Engenharia Eletrotécnica**
**Curso de Mestrado em Eng. Eletrotécnica e de Computadores**

**Disciplina:** Dinâmica Avançada **Data:** 31 / January / 2018

It is compulsory to present photo ID document whenever the teacher in charge of the exam surveillance requests it

Exam without documentation support
The duration of the exam is 1 hour and 45 minutes (no tolerance will be given)
It is forbidden the use of mobile phones during the exam.
Questions values: 1.a) – 3 points; 1.b) – 3 points; 2. – 5 points; 3. – 5 points; 4. – 4 points.

**1.** Consider the following two-link manipulator, which has 2 prismatic joints.

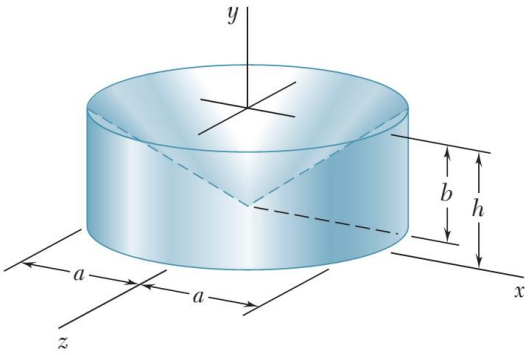


Define the orthogonal base coordinate system ($x$, $y$, $z$) in the place that you consider more adequate and, in case it is needed, define any parameters that allow you to simplify the definition of the requested equations.

**a)** Define and position the required coordinate systems to calculate the direct kinematics of this manipulator using the Denavit-Hartenberg notation.

**b)** Define the Denavit-Hartenberg parameters needed to build the homogeneous transformation matrices $\mathbf{A}_i$ used to calculate the direct kinematics of this manipulator.

**2.** The machine part shown is formed by machining a conical surface into a circular cylinder. The height of the cylinder is $h$ and $b = (1/2) \times h$ is the height of the cone, being $a$ the radius of the cylinder and cone base. Determine the $x$, $y$ and $z$ coordinates (in the indicated coordinate system) of its centre of gravity, assuming that it is made from a uniform and homogeneous material.




**3.** Determine the mass moment of inertia of the machine part with respect to the $y$ axis. The part is made from a uniform and homogeneous material with density ρ.

(In case you are not able to solve exercises 2 and 3, you may assume that $h$ = 200 mm, $a$ = 200 mm and ρ = 7850 kg/m3. In this situation, each of these questions will have the value of 3 points.)

**4.** Assume that it is intended to move a rotational joint of a manipulator, according to a fifth order interpolation in the joint space, between an initial position equal to 60° and a final position equal to 120°. This displacement shall be performed within a time interval of 2 seconds and the joint is initially at rest and ends its movement at rest.

Write the system of equations that will allow you to calculate the coefficients of the polynomial to perform the interpolation of this movement.