- The theory part of the exam will be held from 11:00 to 11:45 and is worth 12 points.
- The practical part will be held from 12:00 to 14:00 and is worth 18 points.
- For the theoretical part of the exam, you are allowed to refer to your personal written notes. (no iPads)
- During the practical part of the exam, you are permitted to use your own equipment and consult online documentation. However, using sites such as Stack Overflow is not allowed.
- There are two tasks in theory part to be completed. Each task must be solved on a separate piece of paper and signed by you to confirm its completion.

1. Consider the following system, where m, g, f_1, f_2 are parameters of the system treated as constants (representing mass, gravity and fixed forces, but the physical interpretation of the system is irrelevant from the problem perspective).

$$m\ddot{x} = -(f_1 + f_2)\sin\theta$$
$$m\ddot{y} = (f_1 + f_2)\cos\theta - mg$$
$$\ddot{\theta} = f_1 - f_2$$

   (a) (2 points) What conditions must the constants m, g, f_1, f_2 meet to guarantee the existence of at least one fixed point in the system? Identify the fixed points that meet these conditions.

   (b) (4 points) Linearize the system's dynamics around those fixed points.

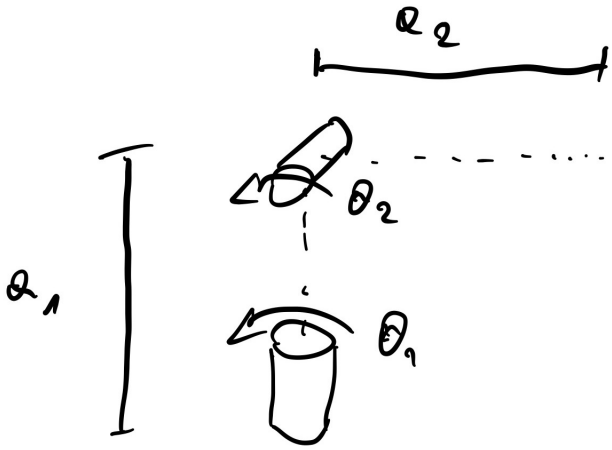

Figure 1: Kinematic chain for problem 2. Note that the axis along the second link is perpendicular (and not parallel), to the axis of rotation of the second joint.

2. Given the visual description of the kinematic chain (figure 1), with two degrees of freedom θ_1 and θ_2 do the following:

   (a) (1 point) Find the forward kinematics $FK(\theta_1, \theta_2)$ of the robot.

   (b) (1 point) Find the workspace of the robot for given a_1, a_2.

   (c) (1 point) Find the inverse kinematics IK of the robot.

   (d) (1 point) Assign frames to the joints of the kinematic chain using the DH-convention.

   (e) (2 points) Create the DH-table for the kinematic chain.