1. Problem 1

Consider the micromanipulator represented in Fig.1. This system is composed of a robotic positioner and an electromagnetic needle.

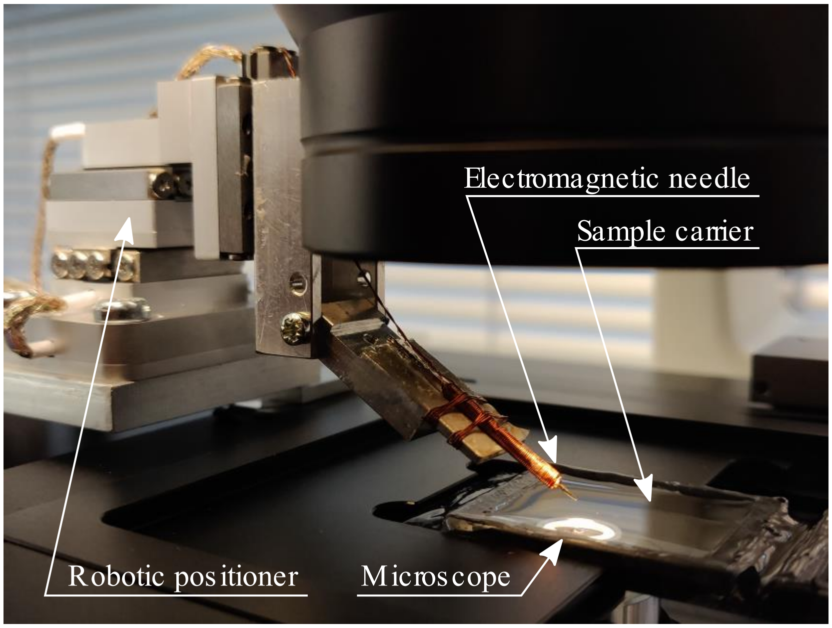

Figure 1 – Robotic electromagnetic needle

When current is supplied to the needle, a magnetic force with the following form is generated:

$$\overrightarrow{F_m} = \frac{2}{3}\pi d_p^3 \rho_p M_p \frac{\beta M_n^2}{(4\beta\delta + 1)^3}\vec{u}$$

Where δ is the distance between the particle and the needle, $\vec{u}$ is the unit vector going from the particle to the needle tip, M_p is the mass magnetization of the particle, M_n is the magnetization of the needle core (which is related to the supplied current), β a parameter related to the shape of the needle tip, d_p is the particle diameter and ρ_p the particle density.

The particle and the needle are placed in a small tank filled with liquid. Thus, the particle is subject to a drag force. This force, opposed to the motion of the particle, is expressed as follows:

$$\overrightarrow{F_d} = -\mathrm{k}\vec{v}_p$$

Where $\vec{v}_p$ is the velocity of the particle and $k = 3\pi\nu_f d_p$ the drag coefficient.

The particles are spherical, and their position is represented by the center of the sphere (x_p, y_p, z_p). The needle is fixed, and its position is represented by the position of its tip (x_n, y_n, z_n).

a) Set up the basic equations of the system. You are supposed to get three differential equations that represent the system.

Consider that the needle and the particle are placed such that no motion on the z axis is recorded.

At the microscale, inertia is, most of the time, negligible because of the size of the objects. We assume that this hypothesis is true for the remaining of the exercise.

b) Rewrite the differential equations based on this hypothesis. You should obtain the following system of equation:

$$\dot{x}_p = \lambda\left(\frac{x_n - x_p}{\delta(4\beta\delta + 1)^3}\right)$$
$$\dot{y}_p = \lambda\left(\frac{y_n - y_p}{\delta(4\beta\delta + 1)^3}\right)$$

Express λ as a function of $d_p, \rho_p, M_p, \beta, M_n, \nu_f$

We assume that M_n is the input of the system and the position and velocity of the particle are the output. For the following questions, we consider these relations:

$$\boldsymbol{M_p = \theta_1 atan(\theta_2 B)}$$

$$\boldsymbol{B = \frac{M_n}{4\beta\delta + 1}}$$

c) Based on these assumptions, design a Simulink model ("model.mdl") of this system. You should also save all the constant used in a script named "constant.m". Be sure to save your model with compatibility for Matlab R2017a.

d) Simulate your system for a duration of 2s and a step input of $M_n = 0.25$. Draw the output of your system in your report. What happen if you increase the simulation time? What does it indicate for the model?

Remark: if your simulation does not work try with different solver and with fixed time step

e) Consider the position of the needle as an input (you are free to choose the input). Simulate the response of the system for this additional input and draw the input/output signal in your report.

f) Instead of the position, we are interested in the velocity norm and direction of the particle. Write the equation allowing you to express the velocity norm and direction as a function of $d_p, \rho_p, M_p, \beta, M_n, \nu_f, \delta, x_p, y_p, x_n, y_n$

g) Modify your Simulink model to compute the new output. Simulate the system and add the velocity norm and direction curve to your report. (you can consider the needle static or as an input).

Parameter	Value	Units	Remark
$\boldsymbol{d_p}$	10.10^{-6}	m	Diameter of the particle
$\boldsymbol{\rho_p}$	3263	$kg.m^{-3}$	Density of the particle
$\boldsymbol{\beta}$	25.10^{4}	$-$	Coefficient
$\boldsymbol{\nu_f}$	1.10^{-3}	$Pa.s$	Fluid viscosity
$\boldsymbol{\theta_1}$	2.05	rad	Angle
$\boldsymbol{\theta_2}$	3.031	rad	Angle
$\boldsymbol{x_0}$	290.10^{-6}	m	Initial position
$\boldsymbol{y_0}$	25.10^{-6}	m	Initial position
$\boldsymbol{x_n\ y_n}$	$0, 0$	m	Initial position

What to return?

You are supposed to submit your assignment to the related link for assignment 2 in MyCourses. Your submission should include one zip file "Assign02_student number.zip" consisting of a pdf file "Assign02_student number.pdf", and two MATLAB files "constant.m", and "model.mdl".

The hard deadline for submission of this assignment is 07.10.2018 at 23.55.