Assignment #2

Modeling and Simulation of Aerospace Systems

AY 2021-2022

POLITECNICO
MILANO 1863

Laboratory sessions - Assignments

Goals

- Contribute towards the final grade
- Relief the workload of the project by spreading it
- Assets for MSc thesis: Matlab, Simulink, and Latex

Assignment evaluation

Weights	Fail	Poor	Good	Excellent
Report	• Major mismatches w.r.t. the assignment • Report awfully written	• Minor mismatches w.r.t. the assignment • Figures and tables not clear • English is poor	• Answers lengthy, but correct • Figures and tables clear • Good English	• Answers concise and clear • Figures and table clear and meaningful • Good English
Code	• Code does not run • Major algorithmic errors • Code not complete	• Minor algorithmic errors • Code not documented • Code takes unnecessary long to run	• Code runs smoothly • Code is fairly documented • Computational efficiency improvable	• Code runs smoothly • Code is well documented • Care is taken to account computational efficiency

Laboratory sessions

- Laboratory sessions <u>will not be recorded</u>
  - we are here to give you answers while you are working

- Timetable

27 Oct	08.30-10.00	Franzese's virtual room
28 Oct	13.30-15.00	LM6 (+ Franzese's room)
02 Nov	10.30-13.00	B8.0.1 (+ Franzese's room)
03 Nov	08.30-10.00	Franzese's virtual room
04 Nov	13.30-15.00	LM.6 (+ Franzese's room)
09 Nov	10.30-13.00	NO CLASS
10 Nov	08.30-10.00	NO CLASS
11 Nov	13.30-15.00	LM.6 (Lecture, + Topputo's room)
14 Nov	**23.30**	**Assignment 2 deadline**

Delivery of assignments

Assigment will be delivered by Webeep:

DEADLINE → Nov 14, 2021, 23:30:00 CET

1) Click on the link to load Assignment 2 in your Overleaf

bit.ly/MSAS_Assignment2_21

2) Fill the report and be sure it is compiled properly
3) Download the PDF and merge it in a zipped file with MATLAB code. Rename it `lastname123456_Assign2.zip`
4) Submit the compressed file by uploading it on Webeep

Assignment 2 - Topics

4 Questions (Theory on Modeling)

4 Exercises (Modeling and Simulation)

Report

Question 2

1) Briefly discuss the physical meaning of the bulk modulus; show how the *effective* bulk modulus is computed. 2) Under what circumstances the fluid resistance yields a linear relation between effort and flow variables? 3) Find the expression of the leakage through a thin annular gap starting from the balance between shear stress and pressure drop.

Write your answer here

- Develop the exercises in one Matlab script; name the file `lastname123456_Assign2.m`
- Organize the script in sections, one for each exercise; use local functions if needed.
- Download the PDF from the Main menu.
- Create a single .zip file containing both the report in PDF and the MATLAB file. The file name shall be `lastname123456_Assign2.zip`.
- Red text indicates where answers are needed; it shoud be removed before delivery.
- In your answers, be concise: to the point.
- **Deadline for the submission: Nov 14 2021, 23:30.**
- **Load the compressed file to the Homework folder on Webeep.**

Exercise

Answer here

Script

LastName123456_Assign2.m

```
% Modeling and Simulation of Aerospace Systems (2020/2021)
% Assignment # 2
% Author: XXX YYY

%% Ex 1
clearvars; close all; clc;

% Develop the exercise here

%% Ex 2
clearvars; close all; clc;

% Develop the exercise here

%% Ex N
clearvars; close all; clc;

% Develop the exercise here

%% Functions
% Define your functions at the end of the script

function y = MyFunction(x)

% Content...
y = 2*x;

end
```

Name of the script

One section per exercise

Functions at the end of the script

Question 1

1) List the stages of dynamic investigation and their meaning. 2) When going from the *real system* to the *physical model* a number of assumptions are made; report the most important ones along with their mathematical implications. 3) For each of the assumptions below, shortly state what sort of simplification may result: i) The gravity torque on a pendulum is taken proportional to the pendulum angle θ; ii) Only wind forces and gravity are assumed in studying the motion of an aircraft; iii) A temperature sensor is assumed to report the temperature exactly; iv) The pressure in a hydraulic actuator is assumed uniform throughout the chamber. 4) List the *effort* and *flow* variables for the domains treated and discuss their similarity.

Question 2

Question 2

1) Briefly discuss the physical meaning of the bulk modulus; show how the *effective* bulk modulus is computed. 2) Under what circumstances the fluid resistance yields a linear relation between effort and flow variables? 3) Find the expression of the leakage through a thin annular gap starting from the balance between shear stress and pressure drop.

Question 3

1) Derive from scratch the mathematical model for RC and RL circuits and express the system response in closed form. 2) Consider a real DC motor and a) sketch its physical model (list the assumptions made); b) derive its mathematical model; c) show how the motor constant depends on the physical parameters.

Question 4

1) Write down the Fourier law and show how it is specialized in the case of conduction through a thin plate; discuss the concept of thermal resistance. 2) Report the equation for thermal radiation in case of a) black body and b) real body and discuss them.

Exercise 1

A miniaturized reaction wheel can be modeled as a couple of massive disks, connected with a flexible shaft (Figure 1). The first disk is driven by a rigid shaft, linked to an electric motor. The motor provides a given torque, while the rigid shaft is subjected to viscous friction, due to motor internal mechanisms. At $t_0 = 0$, the motor provides the torque $T(t) = T_0$.
1) Write down the mathematical model from first principles. 2) Using the data given in the figure caption, and guessing a value for the flexible shaft stiffness k and the viscous friction coefficient b, compute the system response from t_0 to $t_f = 10$ s. 3) Two accelerometers placed on the two disks recorded samples at 100 Hz, which were saved in the file `samples.txt`; the samples are affected by measurement noise. Determine the values of k and b that allow retracing the experimental data, so avoiding parametric errors.

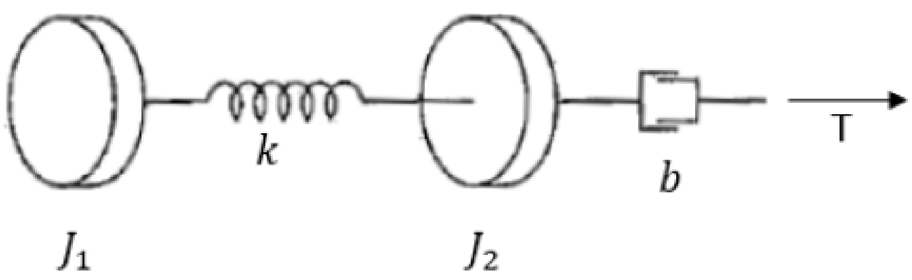

Figure 1: Physical model ($J_1 = 0.2\,\mathrm{kg \cdot m}$; $J_2 = 0.1\,\mathrm{kg \cdot m}$; $T_0 = 0.1\,\mathrm{Nm}$).

Exercise 2

The hydraulic system in Figure 2 consists of an accumulator, a check valve, a distributor, an actuator, and a tank, plus delivery and return lines. At $t = t_{-\infty}$, the accumulator contains nitrogen only. To charge it, the nitrogen undergoes an isothermal transformation from $\{p_{N_2}(t_{-\infty}), V_{N_2}(t_{-\infty})\}$ to $\{p_{N_2}(t_0) = p_0, V_{N_2}(t_0) = V_0\}$, t_0 being the initial time. 1) Assuming incompressible fluid, adiabatic discharge of the accumulator, and no leakage in the actuator, write down a mathematical model that allows computing pressures and flow rates in the sections labeled. 2) Considering the distributor command z in Figure 2, carry out a simulation to show the system response in $[t_0, t_f]$. 3) Determine the time t_e that takes the piston to reach the maximum stroke, $x(t_e) = x_{\max}$, starting from $x(t_0) = x_0$, $\dot{x}(t_0) = v_0$.

- <u>Fluid</u>: Skydrol, $\rho = 890$ kg/m^3.
- <u>Accumulator</u>: $V_{N_2}(t_{-\infty}) = 10$ dm^3, $p_{N_2}(t_{-\infty}) = 2.5$ MPa, $p_0 = 21$ MPa, adiabatic exponent $\gamma = 1.2$.
- <u>Delivery</u>: Coefficient of pressure drop[1] at accumulator outlet $k_A = 1.12$, coefficient of pressure drop across the check valve $k_{cv} = 2$, diameter of the delivery line $D_{23} = 18$ mm; Branch 2–3: Length $L_{23} = 2$ m, friction factor[2] $f_{23} = 0.032$.
- <u>Distributor</u>: Coefficient of pressure drop across the distributor $k_d = 12$, circular cross section, diameter $d_o = 5$ mm.
- <u>Actuator</u>: Diameter of the cylinder $D_c = 50$ mm, diameter of the rod $D_r = 22$ mm, mass of the piston $m = 2$ kg, maximum stroke $x_{\max} = 200$ mm; Load: $F(x) = F_0 + kx$, $F_0 = 1$ kN, $k = 120$ kN/m.
- <u>Return</u>: Diameter of the return line $D_r = 18$ mm; Branch 6–7: Length $L_{67} = 15$ m, friction factor $f_{67} = 0.035$.
- <u>Tank</u>: Pressure $p_T = 0.1$ MPa, initial volume $V_T(t_0) = 1$ dm^3, coefficient of pressure drop at tank inlet $k_T = 1.12$.
- Initial time: $t_0 = 0$, $x_0 = 0$, $v_0 = 0$; $t_1 = 1$ s, $t_2 = 1.5$ s; final time $t_f = 3$ s.

Exercise 2 (2/2)

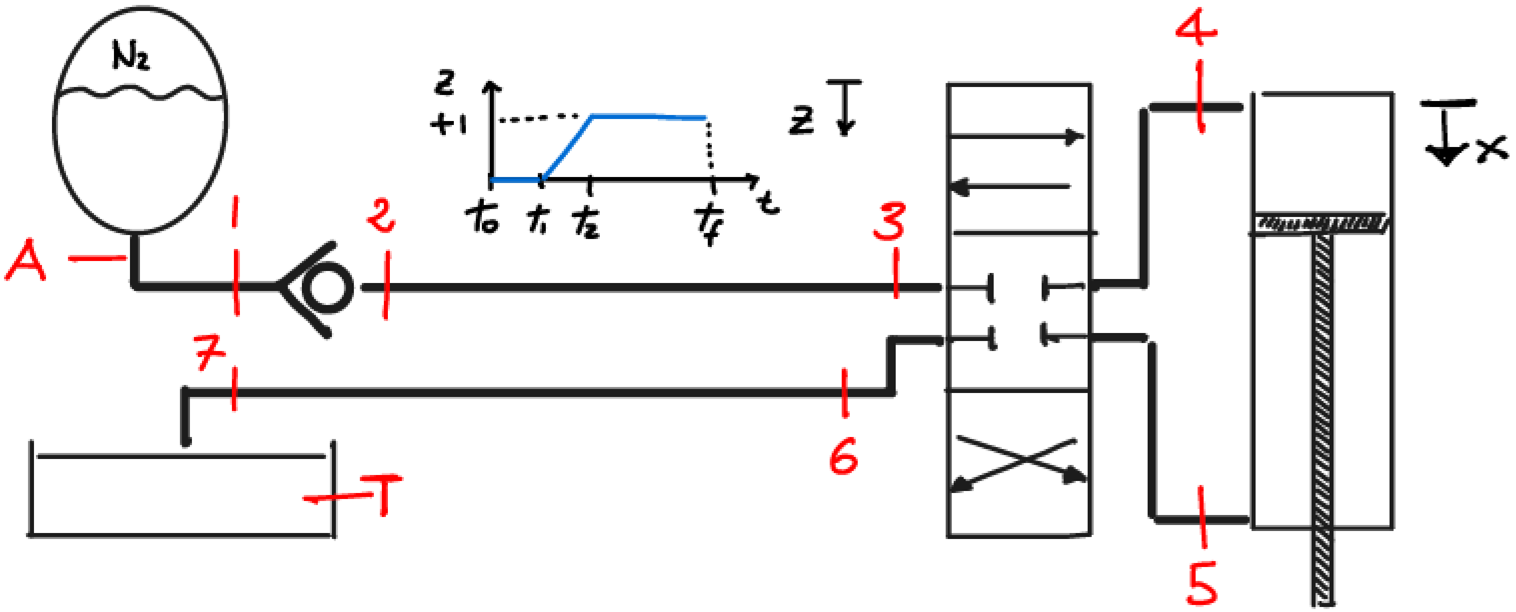

Figure 2: Hydraulic system physical model; assume any other missing data.

Exercise 3

Consider the ideal physical model network shown in Figure 3. The switch has been open for a long time. The capacitor is charged and has a voltage drop between its ends equal to 1 V. Then, at $t = 0$, the switch is closed. 1) Plot the subsequent time history of the voltage V_C across the capacitor. 2) Assume a voltage source characterized by $v(t) = \sin(2\pi f t)\arctan(t)$ having the positive terminal downward inserted in place of the switch. What is in this case the voltage history across the capacitor?

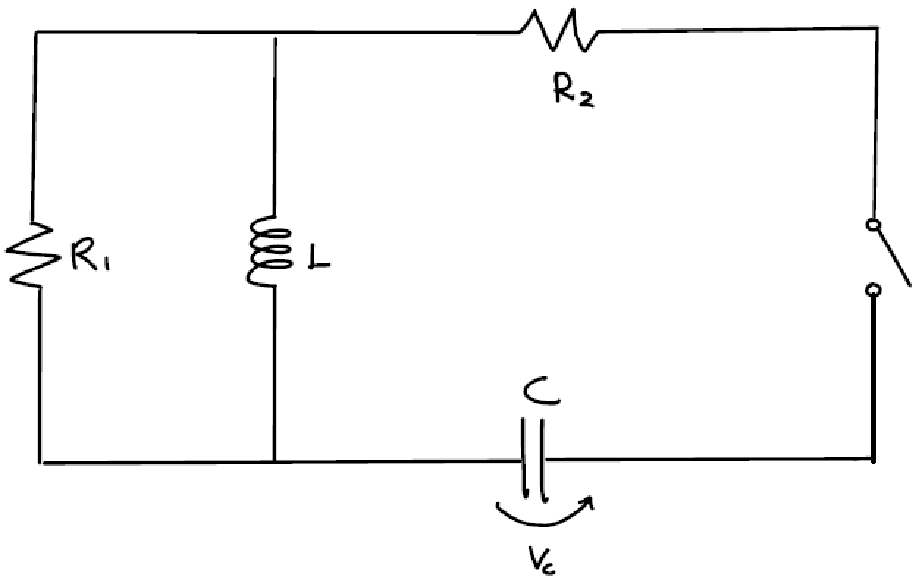

Figure 3: Circuit physical model ($R_1 = 1000\,\Omega$; $R_2 = 100\,\Omega$; $L = 1\,\text{mH}$; $C = 1\,\text{mF}$; $f = 5\,\text{Hz}$.)

Exercise 4

The rocket engine in Figure 4 is fired in laboratory conditions. With reference to Figure 4, the nozzle is made up of an inner lining (k_1), an inner layer having specific heat c_2 and high conductivity k_2, an insulating layer having specific heat c_4 and low conductivity k_4, and an outer coating (k_5). The interface between the conductor and the insulator layers has thermal conductivity k_3. 1) Select the materials of which the nozzle is made of[3], and therefore determine the values of k_i ($i = 1, \ldots, 5$), c_2, and c_4. Assign also the values of ℓ_i (i=1,. . . ,5), L, and A in Figure 4. 2) Derive a physical model and the associated mathematical model using one node per each of the five layers and considering that only the conductor and insulator layers have thermal capacitance. The inner wall temperature, T_i, as well as the outer wall temperature, T_o, are assigned. 3) Using the mathematical model at point 2), carry out a dynamic simulation to show the temperature profiles across the different sections. At initial time, $T_i(t_0) = T_o(t) = 20$ C°. When the rocket is fired, $T_i(t) = 1000$ C°, $t \in [t_1, t_f]$, following a ramp profile in $[t_0, t_1]$. Integrate the system using $t_1 = 1$ s and $t_f = 60$ s. 4) Repeat the simulation in point 3) using a mathematical model implementing two nodes for the conductor and insulator layers.

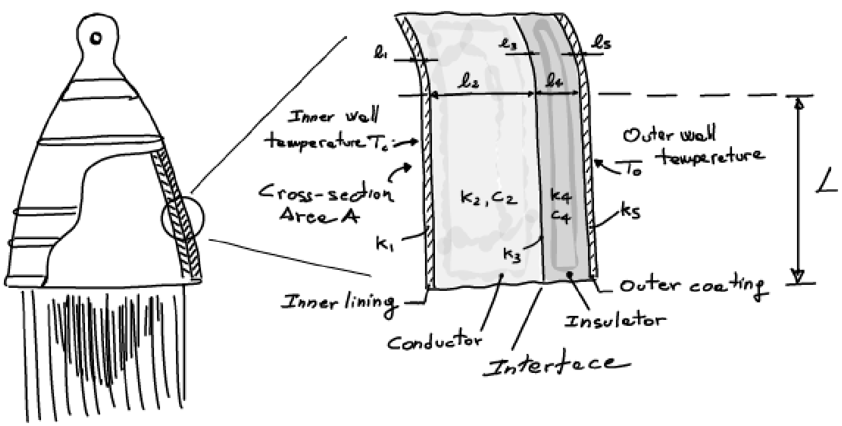

Figure 4: Real thermal system.