MSAS – Final project

Student1, Student2, Student3

1 The real system

Give here a brief description of the real system (the text of the assignment can be omitted). In particular, describe

- The working principle of the real system (e.g., How does it work? For which purpose has it been designed/built?);
- The most relevant elements or components of the system;
- The typical operating conditions, or possible off-nominal conditions;
- Etc.

If needed, complement the description of the real system with any other information that you believe is worth to give; e.g., specify if the real system exists in the real world or it is defined through drawings. Insert a picture or a sketch of the real system (if available).

Allocate max 1 page to this section.

2 The physical model

Starting from the real system, here we define the physical model. The physical model is abstracted by isolating the physics of the real system. In this section,

- The most important effects are isolated and abstracted into equivalent physical components;
- The underlying physical principles are described;
- Although secondary effects are neglected, they are clearly identified and listed (that is, we are fully aware of what is being kept out of the physical model);
- The real system is translated into an equivalent physical model made of ideal components (for instance, real springs are replaced with ideal springs, real resistors by ideal resistors, etc.);
- The physical model is made by lumped-characteristics. This process of lumping should be described. In particular, the hypothesis under which lumping is valid should be mentioned;
- In multi-domain projects (likely all of them), explain how the different physical domain interact each other.
- In general, the overall assumptions under which the physical model is valid should be given.

The outcome is a drawing that is keen to be described mathematically. This drawing summarizes the physical model, obtained, for instance, by applying circuit analogy. In cases where several physical models have been defined during the execution of the project (e.g., with increasing accuracy), summarize the iterative procedure undertaken, as well as all the intermediate models.

Allocate max 2 pages to this section.

3 The mathematical model

In this section, the equations of motion for the physical model are derived, that is, the mathematical model is built. The mathematical model is derived by writing:

- First principles (e.g., conservation of energy, mass, momentum, etc.), and
- Characteristic equation for components (capacitors, resistors, springs, valves, etc.).

All the equations have to be organized appropriately, and reduced to a minimum set of unambiguous statements. The mathematical model is the minimal set of differential-algebraic equations that uniquely describe the dynamics of the system. The mathematical model is prepared (to be later integrated) and put in a state space form.

- If the right-hand side has interesting features, just point them out (for instance, equilibrium points, singularities, points in the phase space in which the mathematical model breaks-up, admissible domain, etc.).
- Linearize the system around a reference condition, which is either an equilibrium point or a working condition. This process may be used to check where the eigenvalues of the system are, to properly choose the numerical integration scheme.
- Alternatively, analyze the system about a reference condition (initial condition, nominal operation, off-nominal condition, etc.).

Allocate max 3 pages to this section.

4 Numerical integration

The mathematical model is here integrated numerically to determine the system response. Numerical integration is performed by starting from a given (or assumed) initial condition. One or more numerical integration schemes can be used, with their selection *duly justified*. In performing the numerical integration, the following questions shall be answered:

- Why did you choose that particular integration scheme?
- And why that integration order and stepsize?
- Did you trade-off between numerical efficiency and accuracy?
- Did you consider choosing alternative schemes?
- What are the performances of your integrator?
- How does the region of numerical stability look like?

Any other information that is worth to mention regarding the numerical integration should be written here. (For instance, if you design your own integrator, or you modify an already-existing one, report the work that you did along these lines).

Allocate max 2 pages to this section.

5 The simulation framework

In this section, describe how the simulation is performed. In particular, with the aid of flow charts, describe

- The numerical framework that has been developed within the context of the project;
- For each block, describe the input and output variables, as well as the tasks accomplished by the block itself;
- The overall solution flow: What is the logic undertaken?

It is suggested to work on this part toward the end of the project work, when the overall scheme developed is clearly defined.

Allocate max 1 page to this section.

6 System response

Determine the system response and eventually feed back the modeling part. In particular,

- Perform a parametric study to check how the system behaves when it operates in either nominal or off-nominal conditions;
- Let the most uncertain parameters of the system to vary (within reasonable bounds), and study the envelope of system responses;
- How does the system response relate to the mathematical and physical models?
- Is the physics caught in the system response? Perform a critically analysis on the numerical model so constructed.
- If a set of experimental data is available, compare the numerical trajectory with the real one.
- If the obtained response is not satisfactory, go back to the modeling part and review either the physical model or the mathematical model. Alternatively, review the numerical integration part.

Allocate max 2 pages to this section.

7 System optimization (Optional)

In case real data are available or system performances need to be improved, carry out a parametric optimization. In parameter optimization,

- Identify the objective function;
- Identify the optimization variables;
- Perform a system optimization. This is likely coupled with a dynamic analysis, therefore the numerical integration shall be nested in the parametric optimization.

Allocate max 2 pages to this section.

General comments (read carefully). Use the list below as a checklist.

Report

1. This is a suggested template. Feel free to use alternative templates.
2. Try to be concise: use max 10 pages (no encyclopedial report). More pages doesn't mean higher grade.
3. Include a list of references to acknowledge the source for data, figures, text, codes, etc.
4. Consider formatting the figures in a readable and clear way (that is, avoid using small fonts, use color codes that make sense, draw visible lines, write readable text, etc.).
5. Write readable formulas, and explain all the coefficients/variables/parameters appearing in the formulas.
6. Reports can be written in MS Word, Latex, Open Office, or any other text editor, provided that the outcome is clear and readable (remember: style matters!).
7. Deliver 1) the report, and 2) the code into the "Homework" folder at least 3 days before the official day of the exam.

Code

8. The code has to run smoothly on first try (no need of manual sharing the path, loading variables, etc.); it will be a problem if it doesn't work.
9. The main file (to run) should be called `main.m` or something similar.
10. Upload one file only (.zip) containing all the deliverables *in the Homework folder in Beep.*

Presentation

11. The presentation should be prepared to last 20 min (no more than 20 slides).
12. Students shall use their own laptop.
13. Students shall get ready to show the Matlab code and the report, if asked (make sure they are both open in the background)

Gather in groups of 3 people, but remember that the exam is a personal exam, not a group exam, therefore student in the same group can be judged in a different way according to the work performed and the feedback gave to the instructor.
Grading is done according to the rubric in Figure 1 using:
Final report Grade = 50% Report + 30% Code + 20% Presentation

Weights ↓	Fail (<18)	Poor (18-21)	Fair (22-25)	Good (26-28)	Excellent (29-30)
Report (50%)	• Major modelling errors (wrong assumptions, missing domains) • Simulation contains several wrong concepts • Report awfully written	• Some modelling errors (assumptions not complete, missing domains) • Simulation part contains several conceptual mistakes • English is poor	• Fair modelling (good assumptions, physics caught) • Simulation not appropriate (wrong integration scheme) • Report not clear, minor issue (typos)	• Detailed modelling (assumptions detailed and justified, all physics considered) • Minor problems with simulation (numerical issues) • Good English	• Accurate modelling (all physics considered, second order effects quantified/modeled) • Good simulation techniques (integrator, numerical issues) • Good English
Code (30%)	• Code does not run • Major algorithmic errors • Code not complete	• Minor algorithmic errors • Code is not documented • Code takes unnecessary long to run (inefficient)	• Code runs smoothly, fairly documented • Computational efficiency improvable	• Code runs smoothly, well documented • Care is taken to computational efficiency • Add-ons are produced	• Code runs smoothly, well documented • Care is taken to computational efficiency • Valuable add-ons are produced
Presentation (20%)	• Major errors in the presentation • Questions are not answered	• Poor presentation • Poor time management • Poor answers to questions	• Fair presentation • Poor time management • Weak answers to questions	• Good presentation • Good management of time • Answers not exhaustive	• Excellent presentation • Excellent time management • Satisfactory answers given

Figure 1: Rubric used for grading.