ELE120 Physical Systems

Assignment 1

Dr Ross Drummond

Assignment weighting

15% of overall module grade

Assignment released

Week 7, autumn semester

Assignment due

Week 12, autumn semester (Blackboard/online submission deadline **Friday 19th December, 5pm**). You may submit your work before the submission deadline (the deadline is not a target!). Do not leave it to the last minute in case you encounter any unforeseen issues. For information on what to submit see 'Assignment briefing' below.

Penalties for late submission

Late submission penalties will be applied according to university policy
https://www.sheffield.ac.uk/ssid/assessment/grades-results/submission-marking

Feedback

The aim is to provide feedback to students within two weeks from the submission deadline.

Unfair means

This is an individual assignment. Do not discuss your solutions/work with others. Submitted work must be wholly your own. Suspected unfair means will be investigated and may lead to penalties. See https://www.sheffield.ac.uk/ssid/unfair-means/index for guidance.

Extenuating circumstances

You must submit an extenuating circumstances form if you have any medical or special circumstances that may have affected your performance on the assignment – or to requests extension to the deadline. See https://www.sheffield.ac.uk/ssid/forms/circs for more information.

Assignment briefing

This assignment/report will assess your fundamental understanding of physical systems, including use of MATLAB/Simulink relevant to the ELE120 module. The assignment is based on the quarter car suspension model of a sports car; this case study was investigated in the lectures and laboratory sessions of the autumn semester.

- Your answers must consist of the MATLAB code and Simulink model(s) used to solve the assignment questions shown below together with any supporting output results (plots/figures etc.) and any other relevant evidence to justify your solution.
- In the report you need to address the questions directly, include your working methodology, justifications/assumptions, as well as include brief discussion of the results as appropriate.
- MATLAB code must have comments that include the title, author, date, the purpose of the code and help details as shown in the MATLAB laboratory sessions.
- In doing the assignment, you should be prepared to use the MATLAB help system and do some personal study to learn about functions or features you may need.
- Read the instructions completely, from top to bottom. Do not skip anything.

Help

Assignment briefing, ELE120 course materials and MATLAB inbuilt help is all that is required. It is stressed that Google is a highly effective tool for troubleshooting MATLAB problems, it can be very useful for helping coding problems such as these. If you need clarifications on the assignment, please, get in touch with the relevant academic staff.

Submitting your work:

You must submit a **report document** and all your relevant **MATLAB/Simulink files**.

<u>Report document</u>

You must submit the completed assignment report to the ELE120 Blackboard page, via Turnitin, as a single document. You must include your University registration number at the top of every page (header). Your report should be word processed, using minimum size font 11, minimum 2.5cm margins all around, and maximum 10 pages in total. No marks will be awarded for content that exceeds 10 pages. The report should be saved as a .pdf file format. Word processing software such as google docs/Microsoft Word or Latex is recommended to produce the report.

<u>MATLAB/Simulink files</u>

In addition to the Turnitin submission, you must also submit – via email – a single zip file (*.zip, *.7z, *.rar) containing your MATLAB and SIMULINK files for the TASK 1 and TASK 4 described below. The following 5 files should be in this zip file.

task1.m	This file contains your MATLAB code for Task 1.
task1sim.slx	This file is your Simulink model for Task 1. Please, pay attention to the extension. Files "*.slx c" cannot be processed and you will get a mark of zero for the MATLAB part if you do not submit the "*.slx" file.
task4.m	This file contains your MATLAB code for Task 4.
task4sim.slx	This file is your Simulink model for Task 4. Please, pay attention to the extension. Files "*.slx c" cannot be processed and you will get a mark of zero for the MATLAB part if you do not submit the "*.slx" file.
roadProfile.mat	This file is provided. It is required for Task 4.

You must email this to Dr Drummond at ross.drummond@sheffield.ac.uk. Use your university email account to do this. Your zip file should be named using the format "ELE120_{my University registration number}.zip". For example, in this format, the zip folder name for the student with Registration number 1111 will be "ELE120_1111.zip".

Important: Before emailing your files, test your zip to make sure your unzipped code works when unzipped to a clean empty folder. This is what will happen when it is marked

Marking criteria

Report, Task 1 Marks will be awarded for correct solutions and methodology, relevant justifications and supporting discussion.	**10**
Task 1 MATLAB and Simulink It will be assessed whether your code runs without errors and repeatedly does so in stand-alone mode (i.e., not depending on pre-existing values from your workspace); not dependent on pre-existing values in workspace; gives the right answers and/or accompanying text and/or correct plots with attention to detail regarding units, labels, etc., and you have shown proficiency in MATLAB with attention to design, readability and consistency (clear design, good indenting, sensible variable names, useful comments, good help).	**10**
Report, Task 2 Marks will be awarded for correct solutions and methodology, relevant justifications and supporting discussion.	**10**
Report, Task 3 Marks will be awarded for correct modelling approach and design, solutions and methodology, relevant justifications and supporting discussion.	**20**
Report, Task 4 Marks will be awarded for correct modelling approach and design, solutions and methodology, relevant justifications and supporting discussion.	**25**
Task 4 MATLAB and Simulink It will be assessed whether your code runs without errors and repeatedly does so; not dependent on pre-existing values in workspace; gives the right answers and/or accompanying text and/or correct plots with attention to detail regarding units, labels, etc., and you have shown proficiency in MATLAB with attention to design, readability and consistency (clear design, good indenting, sensible variable names, useful comments, good help).	**20**
Report quality Use of English, report structure and clarity of writing, quality of figures/plots/diagrams, use of references and justifications of solutions.	**5**
Total:	**100**

Assignment Tasks

The Scenario:

You are a member of a multidisciplinary team who are tasked to design a sports car for an international company. Your responsibility includes the car suspension components, and you are the engineer that will provide recommendations for the suspension design.

Task 1

Using content from the ELE120 lectures and MATLAB laboratory sessions, create a MATLAB script file and Simulink model to simulate a quarter car suspension system.

Using your Simulink simulations, consider the step response of the driver's seat position (with a step amplitude in the reference displacement *r(t)* of 0.1 m) for both when the car is in *'cruise mode'* and in '*sports mode'*. Calculate:

1. the rise time,
2. overshoot,
3. and the settling time (to both 2% and 5% of the final value).

In your report, you should make it clear what specific values you have calculated.

Explain the differences between the two step responses and what these differences are caused by. Comment on how these properties relate to vehicle performance. Be as precise as possible, making clear how changes in the model parameters between the two modes affects the model equations, and hence the response.

In completing *Task 1,* you should:

- Create a single MATLAB script that prompts the user for sports or cruise mode selection,
- Assigns block parameters and any other variables as needed,
- Executes the Simulink model,
- Produces labelled plots of simulation results,
- Display the findings appropriately.
- Then, discuss your findings in the report.
- You may want to use the ``*stepinfo*'' MATLAB function to evaluate the step response.

Task 2

To avoid any damage to the suspension elements, the designers propose to include mechanical 'bump-stops' to the suspension to keep the relative displacement between the wheel and chassis within **+/- 2cm**. This relative displacement being limited is the signal "*y*" in the Simulink model.

1. Implement this change in your Simulink model, using an appropriate **non-linear block**, then plot the wheel's displacement before and after the design change for both cruise and sports modes. Refer to Lecture 3 for examples of non-linear blocks (either a saturation, quantisation, or a deadzone) and pick one that would limit this displacement. Make sure you have identified the correct position in your Simulink model to insert this nonlinear block.
2. Explain the new behaviour you observe in the position of the chassis.

You do not need to submit the MATLAB/Simulink model for this task, but please provide the Simulink model as a figure in the report.

Task 3

Following the design change in Task 2, the chassis movement for the sports mode is now outside the vehicle's performance specifications. These specifications are that the **wheel's absolute displacement (the signal *r+x*)** should have:

- a percentage overshoot less than 72%,
- a settling time (to 2% of the steady-state value) less than 0.25s.

To achieve these specifications, it is proposed to modify the chassis' spring stiffness and damping. The following design options are considered:

Table 1: Table of spring stiffness and damping values.

Damping value	C_2	1000 Ns/m	1500 Ns/m	3000 Ns/m	6000 Ns/m
Spring stiffness	K_2	5000 N/m	13000 N/m	30000 N/m	50000 N/m

For each combination of C_2 and K_2 given in Table 1 (above),

1. Calculate (and present in two tables similar to Tables 2 and 3 below) the percentage overshoot and settling time to 2% of the steady-state value. The ``*stepinfo*'' MATLAB function may prove useful for computing these values. If you are not getting any values which satisfy these two conditions, then make sure you have limited the signal "*y*" in Q2.
2. Comment on the impact of changes in C_2 and K_2 on these performance metrics (the percentage overshoot and the settling time). Be precise; how do these parameter changes influence your model dynamics and how does that then influence the different responses you see?
3. Select an appropriate design from the options given in Table 1 that satisfies the specifications given at the start of this task. Explain why your chosen design is appropriate when considering the driver's comfort- you may want to refer to the step response to justify your design choice.

[4 marks]

Table 2: Change in chassis settling time to 2% of the final value with the spring coefficient K_2 and damping coefficient C_2.

Settling time (s)					
		Suspension damper- $C_2\,(Ns/m)$			
		1000	1500	3000	6000
Suspension spring- $K_2\,(Ns/m)$	5000				
	13000				
	30000				
	50000				

Table 3: Change in chassis percentage overshoot (%) with the spring coefficient K_2 and damping coefficient C_2.

Percentage overshoot (%)					
		Suspension damper- $C_2\,(Ns/m)$			
		1000	1500	3000	6000
Suspension spring- $K_2\,(Ns/m)$	5000				
	13000				
	30000				
	50000				

You do not need to submit the MATLAB/Simulink model for this task, but please provide appropriate information in your report so that your methodology and results are clear.

Task 4

To validate your proposed design, the project manager wants you to simulate the suspension behaviour of the whole axle (two wheels) as an independent suspension using a realistic road profile. The company's test track will be used for this validation after the prototype car is ready. The test track's road profile is provided (in "*roadProfile.mat*"), estimated separately for the left and right wheel**, sampled at 1sec intervals** (90sec for a full lap).

The difference between each wheel's position and the road profile can be considered as an indicator of '*traction*'.

1. Based on the model from Task 2, develop a whole axle model (composed of both wheels on the axle) and calculate the Root Mean Square Error (*RMSE)* for one lap between the wheel's position and the road profile for the cruise mode and the sports mode (for each wheel).
2. Explain what the RMSE values show about the traction in the two different modes.
3. The difference between the position of the left wheel and the right wheel is an indicator of horizontal stability; calculate the Mean Absolute Error (MAE) for each suspension mode and comment on your findings.
4. State and explain the equations you used for these calculations in your report as well as the values obtained.

To complete *Task 4,* you should create a single MATLAB script that

- prompts the user for sports or cruise mode selection,
- assigns block parameters, road profiles and any other variables as needed,
- executes the Simulink model,
- produces labelled plots of simulation results,
- performs the RSME and MAE calculations and displays findings appropriately.