# University of Lincoln Assessment Framework
# Assessment Template 2024-2025

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| **Module Code & Title:** EGR3032 – State Space Control | |
| **Contribution to Final Module Mark:** 50% | |
| **Coursework Title:** Modelling and Control of an Active Vehicle Suspension | |
| **Description of Assessment Task and Purpose:**<br>*You are required to submit a document to answer the questions posted in this coursework assessment brief according to your experience in the lab session. The purpose of this assessment is to judge your knowledge of applying appropriate knowledge of vibration in dynamic balancing of eccentric mass, an ability to find and evaluate accurate and reliable information/evidence and present it in a clear, concise and scientific manner.* | |
| **Learning Outcomes Assessed:**<br>▪ LO1 Apply relevant principles and techniques in continuous-time in state-space methodologies<br>▪ LO2 Use engineering software to fit models to data and design software representation of systems<br>▪ LO3 Adopt a systems approach to the solution of engineering problems, find technical information and acquire experimental data<br>▪ LO4 Present, defend and justify a solution | |
| **Knowledge & Skills Assessed:**<br>• State Space Techniques and Skills<br>• Subject-specific knowledge in Modern Control<br>• Written communication<br>• Critical thinking<br>• IT skills<br>• Problem solving | |
| **Assessment Submission Instructions:**<br>This submission is: <u>Individual work</u><br>All work should be submitted by the deadline stated. Any late submissions will be subject to a lateness penalty in line with the University policy.<br>In cases of technical issues please email your assessment to: soesubmissions@lincoln.ac.uk by the above deadline and copy to module leader. Please include the module code and coursework title in the email subject. | |
| **Date for Return of Feedback:** No later than 15 working days after submission. | |
| **Format for Assessment:**<br>You are required to submit your assessment as a report of around 15-20 pages, in Portable Document Format (PDF) file format, using the turnitin online assessment submission facility on the module Blackboard site. | |
| **Marking Criteria for Assessment:** | |

| ***Part*** | ***Marking scheme*** | ***Marks*** |
|---|---|---|
| 1a | Introduction, setting the context of the problem | 10 |
| 1b | System modelling | 15 |
| 1c | Suspension damper technology | 10 |
| 1d | Matlab/Simulink implementation | 10 |
| 2a | Controller design | 15 |
| 2b | Implementation in Simulink, including rough road | 15 |
| 2c | Performance and implementation | 5 |
| | Conclusions | 10 |
| | Report overall quality | 10 |
| | **TOTAL** | **100** |

***Please note that all work is assessed according to the University of Lincoln Management of Assessment Policy and that marks awarded are provisional on Examination Board decisions which take place at the end of the Academic Year.***

**Feedback Format:**

Feedback will be provided via the turnitin online assessment submission facility on the module Blackboard site.

**Additional Information for Completion of Assessment:**

N/A

**Assessment Support Information:**

Please email any questions to yren@lincoln.ac.uk and/or aaliyu@lincoln.ac.uk

**Important Information on Academic Integrity:**

The use of AI tools are: Not Permitted

All work will be subject to plagiarism and academic integrity checks. In submitting your assessment, you are certifying that this is entirely your own work, without input from either commercial or non-commercial writers or editors or advanced technologies such as artificial intelligence services unless explicitly allowed and referenced. If standard checks suggest otherwise, Academic Misconduct Regulations will be applied.

COURSEWORK BRIEF:

The objectives of the coursework are to:

- Develop and validate a system model through first principles and tests
- Design and implement a controller to achieve desired performance specifications

The assignment has two main parts: system modelling and controller design.

## Introduction

The basic system is shown in Figure 1. The control aim is to apply a computer-controlled force $f_s$ to the suspension in order to improve the performance: ride quality and control of the tyre on the road surface.

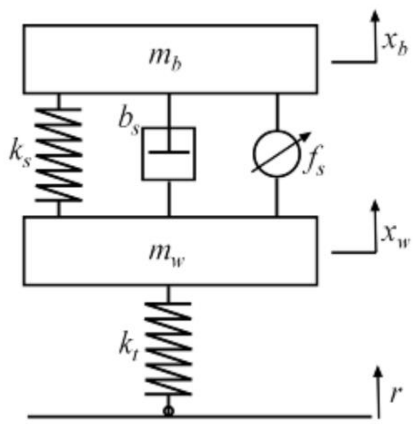


**Figure 1. Suspension Model (quarter car)**

## Part 1 – System Modelling

In the following assume the following parameters for the suspension

| Notation | Quantity | Units |
|---|---|---|
| $m_b$ | 150 | kg |
| $m_w$ | 11 | kg |
| $b_s$ | 690 | N/m/s |
| $k_s$ | 6936 | N/m |
| $k_t$ | 28712 | N/m |

Analyse the dynamics of the suspension:

- Start with a free body diagram and obtain the equations of motion. In the first instance you can assume the actuator force $f_s$ is zero (consider a standard 'passive' suspension) but include the control input it the modelling. Note that there are two inputs, the control input $f_s(t)$ and the road (disturbance) input $r(t)$.
- Write the equations in LTI state-space form.
- Assuming the sensor measures the displacement of the body (in SI units) determine the output equations.
- The suspension damper (coefficient $b_s$) is assumed linear. Find out about the technology of real suspension dampers (shock absorbers) – comment on whether they are linear for real suspensions.

- Find the system poles and check the stability of the (passive) LTI system.
- Use Matlab to simulate the ‘initial condition response’ of the system when either the wheel or body mass has an initial velocity (simulate two cases). Try to relate the simulation results to the system poles (hint: consider the frequencies associated with the poles).
- Use the state-space block in Simulink to re-run the simulations and check that results agree with the Matlab simulations.

## **Part 2 – Controller Design**

In this part you will design a full-state feedback controller, assuming all state variables can be measured.

- Design a state-feedback controller with 5% settling time equal to 1.5s and overshoot equal to 10%.
- Modify the Simulink model to include the state-feedback system. Re-run the initial condition simulations. Comment on whether the design criteria are met.
- Also in Simulink, test the suspension driving over a rough road (e.g., a series of bumps)
- Compare the passive and active suspensions in this case (rough road), using the root-mean-square vertical acceleration of the body mass as the measure of passenger comfort.
- Discuss what other variables might be considered as important for active suspension performance and practical implementation (on a production vehicle).

Note: the report should be in a professional style with title page, contents, summary, references, and a clear structure. Plots from simulation should have axis labels and you should avoid screenshots of Simulink Scope windows. All figures should be numbered and include informative captions. All external information sources should be referenced. Reports are expected to be around 15-20 pages; aim for quality and conciseness, not excessive text. Feel free to use appendices for any “boring details”.