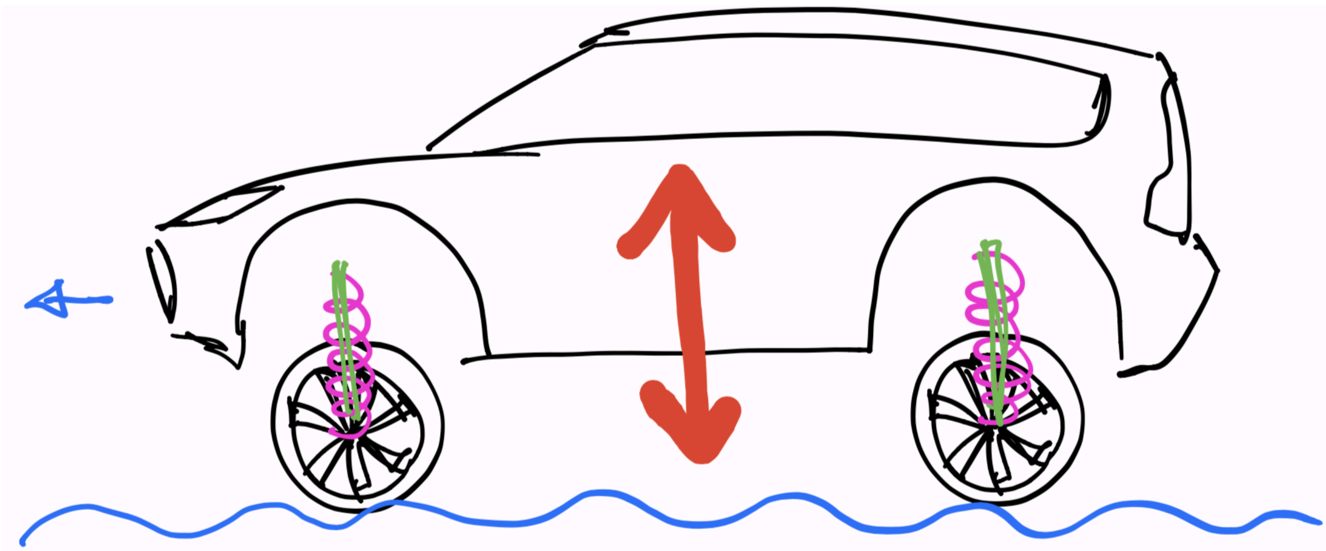
Project 3: Design of Car Suspension (teams of up to three)

In a written report, present a simple custom-built software for tuning and designing car suspension systems

---

Description:



You work for an automotive tuning firm as an NVH (Noise, Vibration and Harshness) engineer. Your boss asks you to do a preliminary, theoretical analysis of the suspension system of any passenger vehicle produced within the last twenty years, and to improve its suspension by introducing adjustable damping, i.e., the shock absorber's damping ratio will be adjustable, either manually by the driver or automatically by the vehicle.

Constraints:

While you have the freedom to choose any make and model sold in the US and produced in the last twenty years, the vehicle must have four wheels – one in each corner – and independent suspension, i.e., each wheel having a spring + damper setup.

You must use the vehicle's "stock condition" as the baseline, i.e., starting point, of your analysis. This includes the mass, spring stiffness, etc. as reported by the manufacturer.

The application of your design work is limited to traveling on continuously bumpy roads only. The road bump height ranges from 2 cm to 10 cm, and the bump spacing from 1 m to 10 m.

Design Parameters:

The new shock absorber design you're going to propose, as mentioned above, needs to be continuously adjustable. Once installed in the vehicle, it will need to provide a wide range of damping, *from nearly undamped to highly overdamped*.

The vehicle speed range should include very low speed (alley, residential area, etc.) and high speed (freeway).

<u>Goals:</u>

The results of this design study need to inform the client so that they can:

1. **Get a sense of the behavior and "operating zone" of the suspension system in order to ensure passenger comfort and safety when the vehicle is traveling on various bumpy roads at various speeds, if the maximum car bounce is not to exceed 10 cm; and**
2. **Predict the vehicle's vertical motion as a function of time (i.e., vibration response) when it is traveling on a stretch of bumpy road of a certain test track, for at least four different operating conditions, each defined by a combination of vehicle speed and damping level.**

<u>Specific Tasks:</u>

For Goal #1

- Build an Octave/Matlab/python code <u>or</u> a Google Sheet that:
  - allows the user to easily specify vehicle and suspension system parameters, including **vehicle mass m, spring constant (stiffness) k, road bump (roughness) height Y_o, road bump spacing λ, and the vehicle speed range** to be considered
  - generates a plot of ***max amplitude of vehicle bounce* (A) vs. *vehicle speed* (v)** for various damping ratios **(ξ) ranging from 0.1 to 50.0**; this plot must automatically update when any of the user-specified parameters changes
  - generates a plot of ***max amplitude of vehicle bounce* (A) vs. *frequency ratio* (r)** for various damping ratios **(ξ) ranging from 0.1 to 50.0**; this plot must automatically update when any of the user-specified parameters changes

Note: Use these **ξ** values: **0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 5, 10, 50**

For Goal #2

- Build an Octave/Matlab/python code <u>or</u> a Google Sheet to solve and plot the vibration ODE, where:
  - at least four different "operating points" (i.e., **ξ** - v combinations from Goal #1) are solve & plotted
  - the plots may be separate, or combined into a single chart
  - all plots must use the same axis range for both y- and t-axes

Overall

- Discuss your findings
- Answer these questions:
    - **What is the effect of changing vehicle speed, road roughness, road bump spacing, and damping level (one at a time) on the vehicle bounce amplitude?**
    - **What operating conditions (vehicle speed, damping level, road conditions) are "worst case scenarios" and thus require special attention?**
    - **What would happen if the vehicle encountered these worst-case conditions?**
    - **What is the "safe operating zone" in your A-vs-v and A-vs-r plots?**
    - **Under what driving conditions should the shock absorber be adjusted to "severely underdamped," "close to critically damped," and "highly overdamped?" Why?**
- Conclude your analysis, noting any limitations, sources of errors and areas of improvement
- Reflect on your learning and journey of working on this project

<u>Deliverables:</u>

Present your work in:

- a written concise technical report (PDF only) <u>and</u>
- a code (text file) <u>or</u> a publicly accessible Google Sheet

The report must be self-contained and self-explanatory, i.e., all information, explanation, and plots must be included in the PDF itself; the client should be able to understand your work without consulting the code or Google Sheet; your code or Google Sheet is a separate software that the client can tinker with.

<u>Rules and Formatting:</u>

- This project may be done <u>individually</u> or in <u>teams of up to three students*</u>
- The report must be electronically generated, including sketches and equations; no freehand is allowed
- You're expected to create and write the entire content of the report; originality and authenticity are highly valued
- Use of generative AI is encouraged for early stages of this project, for research or literature review purposes, subject to UIC's [AI policy]
- The report is limited to 12 pages excluding cover page (if used)
- Content and file requirements
    - Your report must contain typical sections such as **header (or cover page), introduction, technical details including equations and plots, discussion of results, conclusion (including reflection), and references**; appendix is optional.

    - Wikipedia is NOT a credible source of reference
    - Your entire report must be in portrait orientation and has a vertical page flow
    - If used, your Google Sheet must be publicly accessible
    - If used, your Google Sheet must not be edited after you have submitted it to Gradescope (your Google Sheet will show the last edit date to any viewer, so be sure not to modify it after submitting!)
- Code or Google Sheet functionality requirements
    - Your software must include instructions for the user
    - It must allow the user to quickly change values of the parameters described above
    - It must contain plots that dynamically update whenever an input value changes

* Teams must be pre-approved via PPP 3

<u>Submission:</u>

Submit your tech memo PDF and your software (code or Google Sheet link) on Gradescope only. Submissions by email or other means will be disregarded.

Due on Nov 11, 2024 (Monday), at 11:59 pm CST.

Late submissions will be subject to the “half-life” reduction policy according to the syllabus. Requests for accommodation are welcome!

Grading Rubric:

	Fluency			Scaling	Max Possible
	2	**1**	**0**		
Technical Rigor	Report: Assumptions are reasonable and not oversimplified; physics, math, data and graphs are accurate and convincing Software: Data are generated using formulas containing the correct equations; plots are accurate	Some obvious details missing	Farfetched, or missing most details or altogether	1	2
Professionalism	Report: Presentation of work is logical, legible, and easy to follow; format is well-structured; free from grammatical or typographical errors; a joy to read Software: Instructions for the user are clear, changing parameters is easy, plots are well formatted	Some obvious issues with coherence and/or format	Full of errors; hard to follow; illegible	1	2
Lessons Learned, Justification, Reflection	Conclusions are insightful, thoughtful and transparent; goes beyond “pointing out the obvious”; errors and limitations are discussed in detail; reflection is thoughtful and authentic, and suggests future (self-)improvements	Insubstantial or vague	Missing most details or altogether	1	2
				Max Possible:	6