**Car Suspension Modeling**

**Assessment**

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Students should submit their responses from the modeling activity. Students should label individual questions as in the handout.

Instructors can see the answers to the modeling activity

* file "3-034-T-CarSuspensions-TeacherVersion.pdf"

Instructors may use or adapt the grading rubric below, which is also in spreadsheet

* file "RubricGradeSheet.xlsx"

**Additional Assessment Questions (quiz/exam)**

*Note: the modeling project is a significant assessment of these learning goals*

1. Design your own situation, with parameter values, for the given car suspension model. You might use the mass of specific vehicles, for instance, or various initial conditions. Describe what the specific situation means. State and solve the resulting initial value problem.

*[note: Instructors can showcase the resulting variety of models, and then have students write a description comparing two or more.]*

1. The given car suspension model has a right hand side of zero.
	1. Why would this lack of external forces correspond to a smooth road?
	2. State the resulting differential equation for a road with regular ridges, like you may feel when you drive across a bridge. Try a sinusoidal external force with small amplitude.
	3. Model the ride for a road with periodic potholes. *[note: for an advanced student]*
2. List two things this model ignores which are relevant to an actual car suspension. Justify the relevance.

*[Many valid answers, including: the other 3 wheels! the effect of the tire (that's another model for a system!)]*

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*There are many types of learning goals (broad) and outcomes (specific and assessable). Here are a variety from which to choose.*

**Learning Goals: Students will understand that…**

* A differential equation model is the embodiment of a dynamic pattern which allows us to predict the future. Knowing multiple ways to interpret a differential equation can help us solve/analyze it effectively and skillfully apply it as a model.
* Knowing multiple ways to interpret a differential equation can help you solve/analyze it effectively and skillfully apply it as a model.
* Key characteristics of a differential equation determine the validity of solution methods and analytical techniques.
* Crucial understanding of a differential equation model can be found more readily in visualization of the shape and behavior than the algebraic form of the solution.

**General Mathematical Content Student Learning Goals**

Students should learn about Mathematics:

* increase problem solving skills
* develop various strategies for tackling mathematical problems
* be able to use the content skills they have acquired within modeling problems that connect to other disciplines
* gain practice in different modes of thinking such as the effect of changing parameter values, multidimensional thinking, and approximation thinking

**General Mathematical Human Dimensions Goals**

Students should learn about themselves:

* Growth mindset for mathematics
* Mathematics as playful and fun
* Mathematics as exploratory, finding connections

Students should learn about understanding others and/or interacting with them:

* The importance of communicating mathematics

**Student Learning Outcomes specific to this model**

Students should demonstrate knowledge about second order linear homogeneous ordinary differential equations with constant coefficients:

* Solve initial value problems with various parameter values
* Graph the solutions
* Write about the problems and solutions

**Grading Rubric**

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Pts Possible | Comments | Pts Earned |
| **Analyze General Model** |   |   |   |
| 1. State characteristic equation and roots | 3 |   |   |
| 2. Relate ride comfort to existence of a shock absorber. State DE without shock absorber  | 3 |   |   |
| 3. Relate the mass, damping coefficient, and spring constant to "critically damped" | 4 |   |   |
| **Specific DE: Determine Damping** |  |  |  |
| 4. Relate values to constants and variables | 2 |   |   |
| 5. Determine the values of c for a critically damped system. Graph the resulting displacement | 7 |   |   |
| 6. Solve for time to stay within tolerance. Illustrate with a graph. | 7 |   |   |
| **Specific DE: Basic Ride Quality** |   |   |   |
| 7. (a) Graph the resulting displacement. | 7 |   |   |
| 7. (b) Is this a smooth or bumpy ride? underdamped, critically damped, or overdamped? | 5 |   |   |
| 7. (c) Solve for time to stay within tolerance. Illustrate with a graph. | 7 |   |   |
| **Specific DE: Change Mass** |   |   |   |
| 8. Graph without and with increased mass. Briefly describe difference | 7 |   |   |
| **Specific DE: Change Angle** |   |   |   |
| 9. (a) Determine the spring rate correction factor in general. | 4 |   |   |
| (b) Determine new spring constant k to compensate for given angles | 6 |   |   |
| (c) Graph for two given angles. Briefly describe difference | 7 |   |   |
| **Conclusion** |   |   |   |
| 10. Write a short description of how differential equations can model a simple car suspension system.  | 7 |   |   |
| If desired, grade separately for components: \*Summarize the situation you are modeling\*Characterize undamped, underdamped, and overdamped situations\*Indicate the effect of additional mass \*Describe the effect of installation angle |   |   |   |
| **General** |   |   |   |
| Work is correct | 8 |   |   |
| Explanations are complete | 8 |   |   |
| Graphs are well-labeled and easy to read | 8 |   |   |
| **Total** | **100** |   | **0** |