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SIMIODE A SYSTEMIC INITIATIVE FOR MODELING INVESTIGATIONS & OPPORTUNITIES WITH DIFFERENTIAL EQUATIONS

STUDENT VERSION
Drone Heading Home

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Abstract: We describe a comprehensive project in modeling through a two dimensional system of equations and a first order system of differential equations. Students are guided in creating the model in a collaborative, inquiry-based manner but independently analyze it analytically, qualitatively, and numerically. The project contains diverse opportunities for extensions, including analyzing parameter sensitivity and using it in a variety of applied pursuit curve scenarios. The rubric used to guide the project report writing and to evaluate the project is tied to outcomes in the modified Bloom's taxonomy.

SCENARIO DESCRIPTION

You just received a new long-range helicopter drone for your birthday! After a little practice, you try a long-range test of it by having it carry a small package to your home. A friend volunteers to take it 5 miles east of your home with the goal of flying directly back to your home. So you program and guide the drone to always head directly toward home at a speed of 6 miles per hour. However, a wind is blowing from the south at a steady 4 miles per hour. The drone, though, always attempts to head directly home. We will assume the drone always flies at the same height. What is the drone's flight path? Does it get the package to your home? What happens if the speeds are different? What if the initial distance is different? How much time does the drone's battery have to last to get home?

In this project, you will have two submittals:

1. **Draft Report:** After you collaboratively work on developing your model(s) of this scenario in two class sessions, you will submit your introduction to the problem, as well as your draft differential equation model(s). The purpose of this submittal is to ensure you have an accurate model before moving forward and also to receive feedback on that model. See the rubric regarding the introduction and the model description.

2. **Final Report:** After receiving feedback on your model(s) from the instructor, you will submit a final report where you mathematically analyze the model, make predictions, interpret your predictions and conclusions, evaluate those conclusions, and reflect on the project experience. See the rubric for the detailed requirements. Here are some pertinent questions that provide specific ideas for prediction that you should address and you may have more of your own to add:

   - What is the drone's flight path?
   - Does the drone get the package to your home?
   - Can you obtain an estimate of how long the drone's battery has to last to get home? How might you attempt that?

   "What if" questions: Consider some of these "what if" questions and how they affect the pertinent questions:

   - What if the wind or drone speeds are different?
   - What if the initial distance from home is different?
   - Do you have other reasonable questions?

   Do any of those "what if"questions affect battery or other aspects of drone design?

Be sure to utilize the rubric as your guide in writing your final report.

RUBRIC FOR THE FINAL REPORT

Each of the following elements are rated along a range of absent to excellent, depending on the completeness and quality of the work on that element.

Organization: You must have the following organizational elements in the final paper, each with a clear header.

- Cover Sheet (title of your project, your name, your partners' names (if any) and the date)
- Problem Introduction Section
- Model Section
- Mathematical Analysis Section
- Prediction and Evaluation Section
- Reflection Section
- Credits: Give credit to people that assisted you or references you used (if any)

Layout and Formatting: This is a report, not an assignment, so please write this paper in narrative (paragraph) format, except putting equations and formulas on separate lines. Here are further guidelines:

- Narratives in paragraphs. Typed (except mathematical equations which may be handwritten.) 11 or 12 point font.

- Equations and calculations, etc. are on a separate line and easy to read.
- Understandability of graphs. (Suggestion: You may take a picture of hand drawn graphs and of graphs on calculators or other software.)
- Clear identification of graphs in the narratives through labeling of the graphs (e.g., "see Figure 1").
- Graphs are used effectively in the narratives and explanations. In other words, you refer to the graphs and use the graphs in your discussions.

Introduction: Must include:

- Introduction of the problem. (Summarize the problem in your own words.)
- Discuss how this problem may be similar and different from other applied problems you have encountered.

Model: Must include:

- Clear mathematical statement of the model.
- Definitions of variables.
- Explanation of the different parts of the model and how they relate to each other.
- Justification of the model and its parts.

Mathematical Analysis: Must include:

- Qualitative Analysis: Discuss what mathematical information the qualitative analysis gives about the solution.
- Analytical Analysis: Solve and discuss what mathematical information the analytical analysis gives about the solution.
- Numerical analysis: Solve and discuss what mathematical information the numerical analysis gives about the solution.
- Explain: Each analysis should include an explanation of the steps taken analyzing the model. (But note you don't have to state or show every single basic algebraic step.)
- Model verification: Are the results of the model consistent with any data? How? If there is no data, what else can you do to verify if the model results are accurate?
- Compare/Contrast: Compare and contrast the three techniques (graphical, analytical, numerical). What is similar and different? Did they agree with each other? For this problem, in what ways were they useful or not?

Prediction, Interpretation, and Evaluation: Must include:

- Prediction: Make predictions based on the model. See the project directions.
- Interpretations: Be sure to state what your solution and predictions mean or say in terms of the applied problem. This should be done throughout the write-up as necessary.
- Evaluation: Critique the interpretations and predictions. Do the interpretations of the

solution and predictions make sense for that applied problem? Why or why not?

- Evaluation: What might your solutions and predictions imply and why is it important for the people, animals, or objects in the applied problem? Does it imply any actions that should be taken in the future, i.e. do you have any recommendations based on your conclusion?

Reflection: Each person on the project must include separately a reflection with these elements:

- What was the most important thing you learned mathematically or about solving problems and did you learn anything mathematically new?
- What was the most important thing you learned personally and did you learn anything new about yourself? (This could be about how you go about your work, how you communicate, your relationship with others, what you enjoy doing, your attitude towards mathematics, etc.)
- Did you find the project difficult? In what ways?
- Did you find any connections to other disciplines or to courses you have had?
- Did you encounter any technical or non-technical problems?
- Did you encounter or think of other ways to attack the problem?
- Did other mathematical or physical questions arise that would be interesting to investigate?