General Physics 1–Honors (PHYS 101H):
Problem Set 8

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Overview

This is the second of two computational Problem Sets that will help you gain experience with studying numerical solutions to complex problems. You will be introduced to `python` and `Jupyter` notebooks, implemented in Google's `Colab` environment. You will experiment with editing and modifying simple notebooks to carry out numerical analysis of ordinary differential equations (ODEs). These problem sets provide a foundation for future courses in the Department of Physics that will develop your programming skills and knowledge. This Problem Set, in particular, builds on Problem Set 4 and your analysis of one-dimensional motion with air resistance, to extend it to an analysis of two-dimensional motion with air resistance.

This Problem Set is worth 50 points; there are three questions in this Problem Set.

Instructions

The instructions for these computational Problem Sets are a little different than the written Problem Sets, so read the following carefully.

1. Open a browser and access the notebook `drag_2D.ipynb` from the link in Blackboard in Google Colab.
2. **Make a copy and save that copy to your own Google drive**. If you do not do this, your changes will be lost. **Do not edit the original file.** You will use this copy to answer the questions below.
3. Start executing the cells in your copy (by pressing the 'play' button or hitting 'Shift-Enter') to explore the notebook.
4. Answer the questions below and save the results in your notebook. Name your submission `drag_2D_surname.ipynb` (replace `_surname` with your last name).
5. When you are satisfied with your results, download a PDF copy of your notebook, and then upload that PDF to Blackboard as your submission for the Problem Set. **In the comment section of your submission, please include a link to your colab file (and ensure you turn on link sharing so I can see it).**

This Problem Set will provide practice in implementing python commads in Google Colab. You will study the one-dimensional motion of a projectile falling under the influence of gravity in the presence of air resistance (drag).

Question 1 **20pts**

(a) Make four plots, one each of the x and y positions and one each of the x and y components of the velocity, to compare two projectile motions with different initial conditions. You are free to choose your initial conditions, but they must be different and you should identify them clearly.

(b) Calculate the apogee (the highest point reached) and the time of flight (the time taken to land at height $y = 0$ m) for both cases.

(c) (i) Use your velocity plots to estimate the terminal velocities (in the y direction) for your two motions. Compare your numerical estimates with the values predicted by our quadratic resistance model

$$v_{\mathrm{T}} = \sqrt{\frac{2mg}{d\rho A}}.$$

(ii) Comment on whether the x component of the velocity matches your expectations.

If you find that your choice of numbers leads to plots that appear to cut off randomly in the middle, then there may be a numerical instability in the solver, or the solver may have hit an undefined value. Try again with different values (hint: try ones closer to the example values).

Question 2 **15pts**

Make two plots, one of the y position and one of the y component of the velocity, to compare the motion of at least two different projectiles with different properties (mass or radius). Note that you may need to make several functions, each with a different constant k to account for your changes. Look at `drag_1D_surname.ipynb` to see one way this can be done (there are many). Don't forget to call the right function when you are calculating your results. Comment on whether altering the mass and/or the radius has the effect you expect.

Question 3 **15pts**

Make two plots, one of the y position and one of the y component of the velocity, to compare the motion of at least two different projectiles **on two different planets**. In other words, compare the motion of at least two different projectiles in the presence of two different accelerations due to gravity. Note that you may need to make several functions, each with a different constant k to account for your changes. Don't forget to call the right function when you are calculating your results. Comment on whether altering the acceleration due to gravity has the effect you expect.