CLASSICAL PHYSICS TFY 4345 – COMPUTATIONAL EXERCISE 1

This is the first compulsory exercise, return by September 24th at 13:00 in Blackboard. You may work either alone or in pairs. Refer to your partner while returning. Everyone must return a report due to bookkeeping purposes (the same report for pairs). For background information, please check the Appendix on projectile motion under "Learning materials".

Prepare your report using LaTeX. Pay special attention on the quality of figures as these are the most important content (are the labels visible, is the line thickness appropriate, etc.). Do not attach the source code in your report because we do not want to see it. You may program in any language as long as you prepare your own code from scratch.

Assessment: Accepted (1) or requires a revision (0)

1. Projectile motion with air resistance included

First make a program that can calculate projectile motion in 2D ***without air drag***. Use the ***Runge-Kutta algorithm*** (4th order) for numerical routines and remember to consider the effect of time step used (convergence tests, validity of numerical approach). This is crucial! Use a firing angle of $\theta = 45°$ as a benchmark. Compare your numerical solution with the analytical solution (find it out). Note that the Appendix uses the Euler method, not Runge-Kutta. Adapt you algorithm correspondingly.

Initial conditions: Initial speed of the cannon shell, $v_0 = 700$ m/s

Next, calculate the trajectory of a cannon shell including both air drag and the reduced air density at high altitudes. Perform your calculation for different firing angles (θ) and determine the optimal value of the angle that gives the maximum range with the following models and parameters.

Air drag model: Ratio of the drag force ($F_g = -B_2v^2$) parameter over mass, $B_2/m = 4 \times 10^{-5}$ m^{-1} (Appendix, slide 8)

Air density corrections (consider both cases):

1. Isothermic model: $y_0 = k_BT/mg \approx 1.0 \times 10^4$ m, in $\rho = \rho_0 \exp(-y/y_0)$
2. Adiabatic model (see Appendix, slide 9)

Note: Use ***linear interpolation*** to determine the landing point of the cannon shell (when $y = 0$ m) by interpolating between the last point above ground and the point that would have been below ground ($y < 0$ m). See the Appendix, slides 7-9. The equations of air drag and air density correction models are also available therein.

2. Big Bertha (Paris Gun)

The Germans used a long-range cannon in World War I to bombard Paris with 106-kilogram shells. Its muzzle velocity was 1640 m/s at the start of the flight. Find its predicted range, maximum projectile height and projectile time of flight by assuming the same air drag model and B_2 parameter as above and the adiabatic air density model.