

# Propulsion Lab (S/L2) – Ballistic Trajectory Calculation

Reading: Lab 2 Notes — Trajectory Calculation

## Learning Objectives

- Introduction to numerical solution of ODEs
- Determination of numerical integration method accuracy
- Prediction of drag effects on rocket trajectory

## Procedure

Implement a numerical algorithm for integration of the trajectory ODEs given in the notes. The various parameters appearing in the equations,  $m$ ,  $A$ ,  $\Delta t$ , etc. must be easily changable in your program. Using a spreadsheet is suggested, although MATLAB, C, etc. are OK.

Set the parameters in your program to the following baseline values:

$$m = 0.15 \text{ kg}$$

$$A = 0.015 \text{ m}^2$$

$$h_0 = 0 \text{ m}$$

$$V_0 = 40 \text{ m/s}$$

Perform all integrations until just after the maximum altitude is reached.

## Calculations and Reporting

1. Derive the exact solutions  $V(t)$ ,  $h(t)$  for the zero-drag case  $C_D = 0$ .
2. Set  $C_D = 0$  in your program. Perform three separate calculations for  $\Delta t = 0.1\text{s}, 0.05\text{s}, 0.02\text{s}$ . Plot all three  $h_i$  curves on one plot, and also include the exact  $h(t)$  solution.

a) Does your algorithm appear to be *consistent*? (see Lab 2 Notes). Explain.

b) You will be using the spreadsheet to make rocket design decisions in subsequent labs (determine optimum water mass, importance of drag, etc). Based on the results in a), what do you recommend as a suitable  $\Delta t$  to use? State your criterion.

Use your chosen  $\Delta t$  for the next part.

3. Perform three trajectory calculations for  $C_D = 0.1, 0.2, 0.5$ . Plot the resulting  $h_i$ . Comment on the importance of drag reduction for water rocket altitude performance.