

**Computational Physics / PHYS-UA 210 / Problem Set #11**  
**Due November 22, 2019**

You *must* label all axes of all plots, including giving the *units*!!

1. Exercise 8.3 of Newman.
2. Write a routine that integrates the equations for projectile motion:

$$\frac{d^2\vec{x}}{dt^2} = -g\hat{x}_1 - \alpha\dot{\vec{x}}^2, \quad (1)$$

where  $\hat{x}_1$  is the vertical direction. These are appropriate for, say, a golf ball. The initial conditions should be that the object is launched at some angle  $\theta$  from the horizontal at some initial speed in the  $x_0$ - $x_1$  plane. Integrate until the object hits the ground again. Use a Runge-Kutta method from `scipy` to solve this problem and write a routine that finds where the ball hits the ground again.

3. Use Brent's method (either yours or `scipy`'s) to optimize the angle  $\theta$  to get the longest distance.
4. Exercise 8.10 of Newman.