Assignment: how far does a batted baseball fly?

Up until now, you have probably neglected air resistance in most of your work. We know that that approximation breaks down badly in some cases. Solving the equations of motion with air resistance incorporated is something that cannot be done in closed form.

For this assignment, you will compute the distance travelled by a baseball with air resistance included. There are still some effects that we will ignore. In particular, we will ignore the *Magnus force* which is due to the spin of the ball. We will also make a few simplifying assumptions about the drag forces on a baseball.

In terms of the drag coefficient C_D, the cross-sectional area of a projectile A, the density of air, ρ, and its velocity $\vec{v}$,

$$\vec{F} = -\frac{1}{2} C_D \rho A v \vec{v}. \qquad (1)$$

To trace out the flight of the ball, you will start with a height and a velocity for the ball, and then follow through with an integration of the motion in the x direction and the y direction. You can start with the pendulum programs I gave you in class and on the class web site, and figure out how to modify them to do this job. The baseball's motion stops, effectively, when it hits the ground, so when y=0.

You will want all of the following in your header. I am assuming you will do your work in SI units, so the physical constants are correct. I have converted the values of the mass and radius of a baseball into SI units. The drag coefficient is something that actually varies with velocity. I have picked a value that is about right for speeds of about 60 mph or less.

```
#include<stdio.h>
#include<math.h>
#define pi 3.14159265305
#define g 9.8
/*This is g at sea level.*/
#define r_baseball 37e-3
#define mass_baseball 150e-3
/*The above two values come from the Major League Baseball official
rule book */
#define drag_coeff 0.5
#define rho_air 1.2
/*These are the SI units values for the parameters of a baseball and
of air at 20 degrees C at sea level*/
#define deltat 0.001
```

Baseline assignment

1. Using the Runge-Kutta method, find the distance travelled by a baseball for the parameters given in the header file information above, and an initial velocity off the bat of 100 miles per hour, with an initial angle of 30

degrees and an initial angle of 60 degrees relative to being parallel to the ground. Assume that the ball starts at a height of 1 meter. Remember that in the absence of air resistance, these two angles of launch should give the same projectile distance (at least until the ball drops back to 1 meter in height above the ground). Show that air resistance really matters.

2. Do this for several different time steps, including at least three that give nearly the same answer and at least three that give answers which are different, in order to show that you have found the point where the simulation has "converged".

3. Make plots for the results of your simulations.

Challenge problems

For a challenge problem, do one or more of the following:

1. Find, to within a few degrees, at what angle the ball's initial trajectory should be in order to maximize the distance travelled for a ball leaving the bat with a speed of 100 miles per hour.

2. Include the effects of wind on the flight of the ball.

3. Find a plot that describes the real drag coefficient on a ball as a function of velocity and make a function that gives a better approximation to the real drag coefficient, and get a more precise answer.

4. Compare the number of time steps and the computational time needed to get results of the same accuracy using Euler's method and the RK4 method.