PHYS 301
COMPUTER MODELLING PROJECT

Your semester computer modelling project will be due no later than 5 pm on Monday, April 22. Your homework will consist of three components : a computer program, a description of how your program works, and a description of the physics of the problem and how you are solving the physics. The project will count for 10 % of your total semester grade. Details below.

The scenario : In introductory physics, you learned how to solve 2 D trajectory problems with the assumption of no friction. As we have noted several times in class, ignoring friction is not a realistic approximation, but until you have studied more advanced calculus, it is the only approximation you can make in introductory courses. In introductory physics, you learned that in the absence of air friction, a launch angle of 45 yields the greatest range. This is not the case when friction is more accurately taken into account.

For this assignment, you will write a Mathematica program that will (among other things) determine the launch angle that yields the greatest range for a baseball moving through a dissipative medium.

For this problem, we will use a quadratic model of air friction, this means that we model the drag force as :

$$F_{drag} = -k\,v^2$$

where k is some constant (see more details below) and v is the instantaneous speed of the projectile. What is important to recognize here is that:

$$v^2 = v_x^2 + v_y^2$$

so that when an object experiences a quadratic drag force, the drag force in each direction is dependent on the speed in both the x and y directions. Because of this, you cannot simply separate the equations into an x and y component as you could have in the case of no friction or linear air friction.

Fluid dynamics shows us that the constant k can be written as

$$k = \frac{1}{2} C_D\,\rho\,A$$

where ρ is the density of air, A is the cross sectional area of the moving object, and C_D is called the drag coefficient and is related to the aerodynamics and geometry of the moving object.

The program : You will write a Mathematica program that will employ loop controls, numerical methods and recursion relations to determine the optimal launch angle for a baseball (i.e., the launch angle that generates the greatest range for the initial velocity). Use the Mathematica RandomInteger function to generate a launch velocity in the range of 30 to 40 m/s. You may use Mathematica functions that we have not studied this semester, however you may not use DSolve or NDSolve or any other functions that will directly solve the differential equations of motion.

What you will hand in: Your complete assignment will consist of three components :

• The Mathematica program. You will submit this electronically to me (dslavsk@luc.edu) as a .nb file. Please use only your Loyola email address to submit homework to me (that way I know who is sending me the file). Your program will show clearly the logic and steps you use to produce your results. Your output will include explicitly the initial launch velocity, the optimal launch angle, the range for this set of initial conditions, and a graph (on a single set of axes) comparing the computed trajectories of the baseball using these initial conditions in the cases of quadratic friction and the assumption of no friction. You will also determine the time of flight for the ball assuming quadratic friction, and compare this to the time of flight for the same initial launch conditions in the no friction case.

• An explanation of how your program works. You may write this up on a separate sheet or may include this as a series of comment statements embedded in your program. If you write this on separate pages from your program, you may submit this either online or in hard copy, but in either case, before the project deadline.

• A description of the physics you are solving. Also submit a description of the equations you are solving and show how you determined those equations. Since this is likely to require diagrams (and since constructing diagrams in Mathematica is time consuming), you are free (and even encouraged) to submit this as hard copy to me before the project deadline.

Scoring for the Project :

The program will count for 65 % of your total project grade, the description of the physics will count for 25 %, and your explanation of your program will contribute the final 10 %.

To receive full credit for the program, your code will have to execute, will produce the correct and complete output, and should require no manual inspection of your output to determine the optimal launch angle. This last statement means that your code should output a single statement that shows the optimal launch angle; I will give partial (but not full credit) if your program produces a list of values from which I have to visually choose the optimal angle.

Your physics description should be clear, complete and correct and show how you derive the equations that you will model in your program. Similarly, your program comments must allow me to follow each step in your program and also explain the logic of each step.

Finally, your work must be the result of your own independent effort. No credit will be given for projects not meeting this guideline.

Parameters : For this project, assume a baseball is a sphere (it is not exactly a sphere) of mass 0.145 kg and radius of 0.0367 m. Set the value of atmospheric density to 1.2 kg$/m^3$. The drag coefficient actually varies slightly as a function of velocity, but for this project use a constant experimentally determined value of 0.46. Use the standard value for the acceleration of gravity near the surface of the Earth.