# LAB 02-6: Modeling motion of a projectile with air resistance

In this activity, you will model the motion of a projectile with air resistance. We will refer to the projectile as a ball; however, it can represent a skydiver, for example, by choosing appropriate values for the mass and drag coefficient. We will begin by modeling the motion of a BASE jumper, which is a person who jumps from structures such as Buildings, Antennae, Spans, and Earth (BASE, get it?).
Before you begin, write down the following data that you will need for your model. Again, we'll call the object "ball" though in this case, it represents a BASE jumper.

| | |
|---|---|
| mass of ball | 100 kg |
| drag constant | 0.31 |
| magnitude of Earth's gravitational field near Earth's surface | 9.8 N/kg |
| gravitational force on the ball by Earth | $< 0, -mg, 0 >$ |
| force on the ball by air resistance | $-D\|\vec{v}\|^2\hat{v}$ |
| initial position of the ball | $\langle 0, 800, 0\rangle$ m |
| initial velocity of the ball | $\langle 0, -0.01, 0\rangle$ m/s |

## Writing your program

It is helpful to start with a previous program, as opposed to starting one from scratch.

**Start with a previous program**

1. Open your previous program that modeled the motion of a projectile.
2. Save this file with a new name like `drag.py`.
3. Run the program just to remind you what it does. Note that it shows the projectile, the ground, the path of the projectile, and graphs of x vs. t, $v_x$ vs. t, y vs. t, and $v_y$ vs. t.
4. Change the initial conditions so that the program models a BASE jumper who is jumping from rest from a height of 800 m.
5. Change the radius of the ball (or actually BASE jumper) to 20 m. This will allow us to see it in the animation window. Otherwise, it will be too small to see in the simulation. I call this "eye candy" because it is only for viewing pleasure and is inconsequential regarding the outcome of our model.
6. Define a constant $D$ that is the drag coefficient. Put this in your program where you define other constants and initial conditions.
7. The net force is

$$\vec{F}_{net} = \vec{F}_{grav} + \vec{F}_{drag} \tag{1}$$

As a result, you have to calculate each force and add them together. This occurs inside the while loop. Here is how you calculate the forces and the net force. Study each of these lines and know what each line does. Edit your while loop so that you correctly calculate the net force on the BASE jumper.

```
vhat=ball.v/mag(ball.v)
Fair=-D*mag(ball.v)**2*vhat
Fgrav=vector(0,-ball.m*g,0)
Fnet=Fgrav+Fair
```

8. Note that it was important for us to make the initial velocity VERY small, but not zero. When calculating the unit vector for the velocity, we must divide by the magnitude of the velocity. If the velocity is exactly zero, then this calculation gives $0/0$ which is a problem. Making the initial y-velocity very small, like -0.01 m/s prevents us from getting an error on this line of the program.

9. Comment out any print statements since they slow down the simulation.

10. Run your simulation.

11. Add a print statement *after the while loop* (meaning outside the while loop after the while loop has completed) to print the clock reading, position, and velocity of the ball.

## Application

Use your program to answer each of the following questions. You should only have to change constants or initial conditions to answer the questions.

1. What is the terminal speed for the BASE jumper, using $m = 100$ kg and $D = 0.31$.

2. Suppose that another BASE jumper has a total mass of 200 kg. Will that jumper have the same terminal speed, a greater terminal speed, or less terminal speed as the 100-kg jumper, if the drag constant is the same? Use your model to answer the question.

3. Suppose that another 100-kg jumper uses a special suit to increase drag to $D = 0.5$. If both jumpers (same mass, but different D) jump at the same instant, how much time will elapse between when the two jumpers reach the ground?

4. Suppose that a 100-kg jumper wants to have a terminal speed of 2 m/s with the parachute fully deployed. What must be the drag coefficient of the parachute?