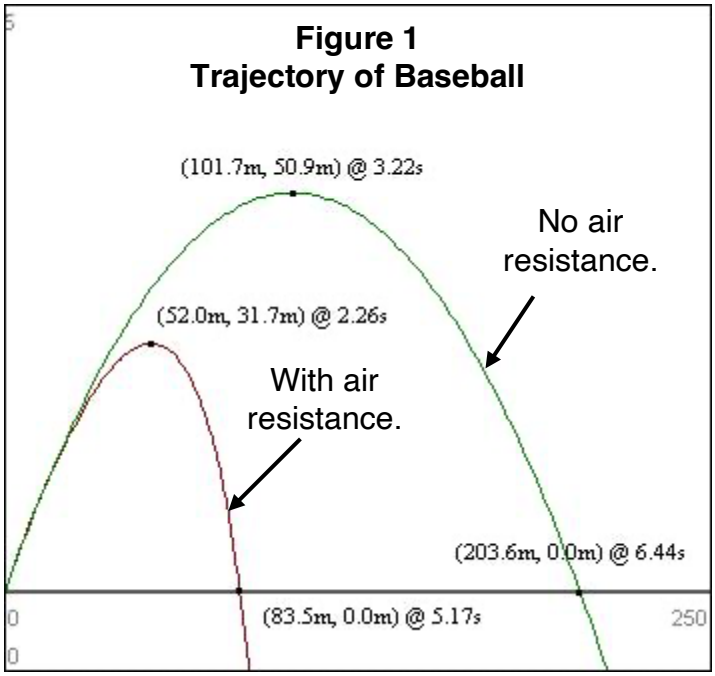
Ballistics

Ballistics is the branch of physics that seeks to understand the flight of airborne objects under the influence of gravity and air resistance. Newton's laws of motion, calculus, and kinematic descriptions of motion combine to produce equations that describe an airborne object's path. The challenge of ballistics is to accurately account for the influence of air resistance on the object's path. In some instances, air resistance can have significant effects. When ignored, the predicted path is quite unrealistic. **Figure 1** shows computer-generated paths of a baseball - with and without air resistance. The graph shows the rather dramatic differences that result from considering air resistance.

Figure 1
Trajectory of Baseball



The degree of influence that air resistance has upon an object depends on a variety of factors. A **ballistic coefficient** is often used to describe an object's tendency to overcome air resistance while in flight. **Figure 2** displays the formula for the ballistic coefficient (BC). One of the variables - drag coefficient (C_d) - is abnormally complicated. The value of C_d depends on the object's shape. **Figure 3** shows drag coefficients for five objects with different shapes moving at the same speed.

Figure 2

$$BC = m/(C_d \cdot A)$$

m = mass of object
C_d = drag coefficient
A = cross-sectional area

The amount of air resistance experienced by an object in flight also depends upon the speed of the object. For lower speeds, the air resistance varies with the square of the speed. So a doubling of the speed causes the air resistance to be four times greater. A tripling of the speed causes the air resistance to be nine times greater. As speeds increase, the amount of air resistance still depends upon speed, but not necessarily upon the square of the speed. So at high speeds, a two-fold increase in speed increases the air resistance, but not by a factor of four.

Figure 3

Shape	Drag Coefficient
Sphere	0.47
Half Sphere	0.42
Cone	0.50
Cube	1.05
Angled Cube	0.80