SIMIODE Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations

DR Brian Winkel, Director
Emeritus Professor, Mathematics, US Military Academy
26 Broadway, Cornwall NY 12518
845-534-4887 BrianWinkel@simiode.org

Article Review and Annotation

Peastrel, M., R. Lynch Lynch, and A.Armenti, Jr. 1980. Terminal velocity of a shuttlecock in vertical fall. *American Journal of Physics*. 48(7): 511-513.

Article Abstract: We have performed a straightforward vertical fall experiment for a case where the effects of air resistance are important and directly measurable. Using a commonly available badminton shuttlecock, a tape measure, and a millisecond timer, the times required for the shuttlecock to fall given distances (up to almost ten meters) were accurately measured. The experiment was performed in an open stairwell. The experimental data was compared to the predictions of several models. The best fit was obtained with the model which assumes a resistive force quadratic in the instantaneous speed of the falling object. This model was fitted to the experimental data enabling us to predict the terminal velocity of the shuttlecock (6.80 m/sec). The results indicate that, starting from rest, the vertically falling shuttlecock achieves 99% of its terminal velocity in 1.84 sec, after falling 9.2 m. The relative ease in collecting the data, as well as the excellent agreement with theory, make this an ideal experiment for use in physics courses at a variety of levels.

This paper offers a set of data on a falling shuttlecock (the moving object in badminton) in air. How the author's collected the data is described fully and can be replicated easily by modern equipment, e.g, Vernier Software Motion Detector. The model is developed from Newton's Seond Law of Motion as

$$m*v'(t) = m*g - k*m*v^r \text{ , } v(0) = 0.$$

The purpose of the paper is to discern which model, $r = 1$ or $r = 2$, fits the data best. The authors show that the quadratic resistance model, $r = 2$, fits best. They also study the ideal model, i.e., $\underline{k = 0}$, and compare this model with the two candidates above. They use an analysis involving the terminal velocity, v_T, which in the quadratic case is given by

$$(v_T)^2 = g/k \text{ ,}$$

and solving for distance as a function of time in which v_T is involved in each case.

This approach could serve as a fine modeling activity in which the teacher uses the paper to guide discovery and analysis.