Aerodynamics of a shuttlecock

FizziQ activity · High school · 40 min

Scan to open in FizziQ

Frame by frame, students track a badminton shuttlecock in the FizziQ Kinematics module, compare its path to a parabola and quantify aerodynamic drag. High school.

Learning objectives

- Analyze the trajectory of a badminton shuttlecock using video-based kinematic analysis in FizziQ
- Compare the real trajectory with the theoretical parabolic trajectory of an ideal projectile
- Observe the decay of horizontal velocity due to aerodynamic drag
- Understand the role of drag coefficient and frontal area in determining air resistance
- Apply curve fitting tools to characterize the deviation from parabolic motion

Instruments and sensors

Video (kinematics) analysis module · Camera

Materials

- Smartphone or tablet with the FizziQ application
- 'Badminton' reference video from the FizziQ video library
- FizziQ experiment notebook for graphing and curve fitting
- Optional: spreadsheet for additional analysis
- Note: the protocol remains adaptable to any comparable video analysis tool.

Protocol

1. Open FizziQ and navigate to the Kinematics module. Load the 'Badminton' video from the FizziQ resource library.
2. Before starting the analysis, identify a reference scale in the video (e.g., the height of the net, the court markings, or a player's height). Set the scale in FizziQ.
3. Set the origin of the coordinate system at the point where the shuttlecock is struck by the racket.
4. Begin frame-by-frame tracking by clicking on the shuttlecock's position in each video frame. Start from the moment of impact.
5. Track the shuttlecock through at least 15-20 frames covering the entire flight from hit to landing.
6. Adjust the interframe interval if needed. An interval of about 1/30 to 1/15 second (every 1-2 frames) usually gives good results for a badminton shot.
7. After completing the tracking, examine the position-position graph (y vs. x) in the FizziQ notebook.
8. Note the shape of the trajectory. It should show a steeper descent compared to a symmetric parabola, with the shuttlecock falling more vertically at the end of its flight.
9. Use the FizziQ curve fitting tool to fit a parabola ($y = ax^2 + bx + c$) to the data. Observe how well or poorly the parabola matches the real trajectory.
10. Now examine the horizontal velocity (v_x) as a function of time. For an ideal projectile, v_x should be constant. For the shuttlecock, it should decrease significantly over time.
11. Plot the horizontal velocity graph and note the exponential-like decay characteristic of a velocity-dependent drag force.
12. Compare the actual trajectory with the ideal parabola and identify the regions of greatest deviation. Explain the physical reasons for the differences.

Expected results

The position-position plot should reveal a clearly asymmetric trajectory: the ascent phase may approximate a parabola, but the descent is much steeper, with the shuttlecock dropping almost vertically. A parabolic fit will show significant residuals, especially in the second half of the flight. The horizontal velocity graph should show a rapid, roughly exponential decay from the initial value (which could be 20-50 m/s depending on the shot) to near zero by the time the shuttlecock reaches its apex. The vertical velocity will also be affected: the upward deceleration is faster than free-fall alone, and the downward acceleration is slower than g due to drag. Pointing errors of ±1-2 pixels are typical and will introduce scatter in the velocity calculations, particularly for closely spaced points.

Questions

- Why does the shuttlecock's trajectory deviate so dramatically from a parabola, while a basketball's does not?
- How does the drag coefficient of a shuttlecock compare to that of other sports projectiles?
- What would the trajectory look like if there were no air resistance? Sketch the theoretical parabola for comparison.
- Why do badminton shuttlecocks have a conical skirt of feathers rather than being solid spheres?
- How does the initial speed of the shuttlecock affect the shape of its trajectory?
- What is the terminal velocity of a badminton shuttlecock, and how does this relate to the observed trajectory?

Going further

- Compare the shuttlecock trajectory with that of a basketball or tennis ball from the FizziQ library to visualize the effect of different drag coefficients
- Record your own badminton shot video and analyze it with FizziQ, comparing soft and powerful shots
- Attempt to model the trajectory numerically by adding a velocity-dependent drag force to the equations of motion
- Investigate how the orientation of the shuttlecock during flight affects its aerodynamic properties
- Compare trajectories of feathered and plastic shuttlecocks to assess differences in drag characteristics