Parabolic trajectory: basketball

FizziQ activity · High school · 40 min

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High school students track a basketball shot frame by frame in FizziQ's Kinematics module on a smartphone, then fit a parabola to verify projectile motion.

Learning objectives

- Analyze the trajectory of a basketball during a shot using video-based kinematic tracking in FizziQ
- Verify that the trajectory follows a parabolic path consistent with projectile motion theory
- Apply quadratic curve fitting to determine the equation of the trajectory
- Estimate the initial velocity and launch angle from the fitted parameters
- Evaluate the precision of manual frame-by-frame tracking through residual analysis

Instruments and sensors

Video (kinematics) analysis module · Camera

Materials

- Smartphone or tablet with the FizziQ application
- "Basketball" video accessible via FizziQ's resource library
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any comparable video analysis tool.

Protocol

1. Open FizziQ and go to the Kinematics module. Load the 'Basketball' video from the FizziQ resource library.
2. Identify a reference scale in the video. The basketball hoop height (3.05 m) or the diameter of the ball (24.3 cm for a standard men's ball) are good references.
3. Set the scale in FizziQ by clicking on two points of known separation in the video.
4. Define the origin of the coordinate system (e.g., the point where the ball leaves the player's hands) and orient the axes with x horizontal and y vertical.
5. Begin frame-by-frame pointing: click on the center of the ball in each successive frame. Start from the moment the ball leaves the shooter's hands.
6. Track the ball through its entire flight path until it reaches the basket or goes beyond the frame. Aim for at least 12-15 data points.
7. Adjust the interframe interval (e.g., every 2 or 3 frames) to ensure the data points are well-separated spatially, reducing relative pointing errors.
8. After completing the pointing, view the y vs. x position graph in your FizziQ notebook. The shape should resemble a downward-opening parabola.
9. Use the FizziQ curve fitting (interpolation) tool to fit a quadratic function $y = ax^2 + bx + c$ to the data.
10. Record the coefficients a, b, and c. From the coefficient a, calculate the initial horizontal velocity using v_0□ $= \sqrt{(-g / 2a)}$, where $g = 9.81\ m/s^2$.
11. Estimate the launch angle θ from the coefficient b, since $b = \tan(\theta)$ for a trajectory starting at the origin.
12. Evaluate the quality of the fit by examining the residuals (differences between measured and fitted positions). Discuss sources of error.

Expected results

The y vs. x graph should display a clear downward-opening parabola. The quadratic fit should yield a coefficient of determination (R^2) above 0.99 for carefully tracked data. Typical values for the quadratic coefficient a range from -0.15 to -0.30, depending on the initial speed. From this, the initial horizontal velocity is typically 4-6 m/s for a standard shot, giving a total initial speed of 7-8 m/s at a launch angle of 45-55°. The residuals should be small (a few centimeters at most) and randomly distributed, indicating a good parabolic fit. Systematic deviations, if present, would suggest either air resistance effects or pointing inaccuracies. The largest source of error is typically the manual pointing precision, which depends on video resolution and ball visibility.

Questions

- Why is the trajectory of a basketball well described by a parabola while that of a shuttlecock is not?
- How does the launch angle affect the shape of the parabola and the maximum height reached?
- From the equation $y = ax^2 + bx + c$, what physical information can you extract about the shot?
- What is the optimal launch angle for a three-point shot, and why is it not exactly 45°?
- How would the trajectory change if the ball had a significant spin? Does the Magnus effect play a role?
- What sources of error are most significant in this type of kinematic analysis?

Going further

- Record and analyze your own basketball shot, comparing short-range and three-point attempts
- Compare the trajectories of shots from different distances and determine how the initial speed and angle change
- Analyze a free throw versus a three-pointer to compare launch parameters
- Use the kinematic data to calculate the ball's velocity and acceleration at each point and verify that the horizontal velocity remains approximately constant
- Attempt the analysis with a different sport (soccer throw-in, volleyball serve) and compare the trajectories