# Measuring g by video analysis

FizziQ activity · High school · 40 min

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Frame-by-frame tracking of a ball's parabolic flight in FizziQ's kinematics module on smartphone gives high school students two independent measurements of g.

## Learning objectives

- Determine the acceleration of gravity experimentally using video-based kinematic analysis
- Apply two independent methods: linear fit of vertical velocity versus time, and quadratic fit of vertical position versus time
- Compare the two experimental values of g with each other and with the accepted value
- Evaluate measurement uncertainty and identify the dominant sources of error
- Understand the equations of uniformly accelerated motion through direct measurement

## Instruments and sensors

Video (kinematics) analysis module · Camera

## Materials

- Smartphone or tablet with the FizziQ application
- 'Parabola' video from the FizziQ library or personal video of an object in free fall
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any comparable video analysis tool.

## Protocol

1. Open FizziQ and navigate to the Kinematics module. Load the 'Parabola' video from the FizziQ resource library, or import your own video of a ball in free flight.
2. Identify a reference scale in the video (e.g., a meter stick, the height of a person, or a known distance between two objects). Set the scale in FizziQ.
3. Define the coordinate system with the y-axis pointing upward and the origin at a convenient location.
4. Track the ball frame by frame by clicking on its center in each successive frame. Collect at least 15-20 data points spanning the full trajectory.
5. After tracking, examine the y vs. t (vertical position versus time) graph. It should be a downward-opening parabola.
6. Method 1: Use FizziQ's curve fitting tool to fit a quadratic function $y = y_0 + v_0 t - \frac{1}{2}gt^2$ to the y(t) data. Extract the coefficient of the $t^2$ term and calculate g.
7. Method 2: Examine the v_y vs. t (vertical velocity versus time) graph. It should be a straight line with a negative slope.
8. Fit a straight line to the v_y(t) data. The slope equals -g. Record this value.
9. Compare the two estimates of g. They should agree within experimental uncertainty.
10. Also check the horizontal velocity v_x(t). It should be approximately constant throughout the flight, confirming negligible air resistance.
11. Calculate the percentage error of each estimate relative to the accepted value of 9.81 m/s².
12. Discuss the sources of uncertainty: scale calibration, pointing precision, video frame rate, air resistance, and timing accuracy.

## Expected results

Both methods should yield values of g between 9.0 and 10.5 $m/s^2$, with typical errors of 5-10% for careful measurements. The quadratic fit to y(t) tends to be more robust because it uses all the data simultaneously, while the velocity method amplifies pointing noise through numerical differentiation. The horizontal velocity should remain approximately constant (within ±10%), confirming that air resistance is negligible for a heavy ball over short distances. Common sources of systematic error include inaccurate scale calibration (which shifts g proportionally), parallax in the video, and motion blur at high speeds. The coefficient of determination for the quadratic fit should exceed 0.99.

## Questions

- Why does the quadratic fit method generally give a more precise result than the velocity-slope method?
- What assumptions does this analysis make about air resistance? When would these assumptions break down?
- How would you modify this experiment to measure g more precisely?
- Why is the horizontal velocity approximately constant while the vertical velocity changes linearly?
- What factors cause the value of g to vary slightly from one location to another on Earth?
- How does the frame rate of the video affect the precision of the measurement?

## Going further

- Compare g values obtained from videos of different objects (tennis ball, basketball, marble) to verify that g is independent of mass and size
- Record your own free-fall video from a known height and analyze it to determine g
- Repeat the analysis with different interframe intervals and evaluate how this affects precision
- Use the method to determine g on another planet by analyzing a video of the Apollo astronauts on the Moon
- Combine this kinematic method with a pendulum measurement of g and compare the results