Trajectory of a football shot

FizziQ activity · Middle school · 30 min

Scan to open in FizziQ

Using a chronophotograph of a kicked football, students track the ball in FizziQ's kinematics module on smartphone or tablet and show the motion is not uniform.

Learning objectives

- Analyze a football chronophotograph using FizziQ's kinematic tracking module
- Measure the successive positions of the ball at regular time intervals
- Calculate the instantaneous speed at different points and determine whether the motion is uniform
- Identify the deceleration caused by friction and air resistance
- Understand the difference between uniform and non-uniform motion through quantitative analysis

Instruments and sensors

Video (kinematics) analysis module

Materials

- Smartphone or tablet with the FizziQ application
- 'Football' chronophotograph available in the FizziQ resource library
- FizziQ experience notebook
- Note: the protocol remains adaptable to any comparable video analysis tool.

Protocol

1. Open FizziQ and navigate to the Kinematics module. Load the 'Football' chronophotograph from the FizziQ resource library.

2. Identify the time interval between successive positions in the chronophotograph (this information should be provided with the image).

3. Set the scale using a known reference in the image (ball diameter = 22 cm, pitch markings, or indicated scale).

4. Point to the center of the ball at each successive position shown in the chronophotograph. Track all visible positions.

5. After tracking, examine the position vs. time graph. If the motion were uniform, this should be a straight line.

6. Note whether the spacing between consecutive positions is constant (uniform motion) or decreasing (decelerating motion).

7. Calculate the speed between each pair of consecutive positions: $v = \Delta x / \Delta t$.

8. Plot the speed versus time graph. For decelerating motion, this should show a decreasing trend.

9. If the deceleration is approximately constant, fit a straight line to the v(t) data. The slope is the deceleration (negative acceleration).

10. From the deceleration, estimate the friction force on the ball: $F = m \times a$, where $m \approx 0.43$ kg for a standard football.

11. Compare this friction force with the ball's weight ($mg \approx 4.2$ N) and calculate the friction coefficient $\mu = a / g$.

12. Discuss whether air resistance or ground friction is the dominant decelerating force for a rolling ball on grass.

Expected results

The chronophotograph should show decreasing spacing between consecutive ball positions, clearly indicating non-uniform (decelerating) motion. Initial speeds after a kick typically range from 5-15 m/s, decreasing by about 0.5-2 m/s per second due to rolling friction and air resistance. The speed versus time graph should show a roughly linear decrease for a rolling ball on grass, with a deceleration of 1-3 m/s². The effective friction coefficient for a football on grass is typically 0.2-0.5, depending on grass length and wetness. Air resistance becomes significant only at higher speeds (above 15 m/s for a football), so for moderate-speed rolling, ground friction dominates.

Questions

- What evidence from the chronophotograph shows that the ball's motion is not uniform?
- What forces cause the ball to decelerate? Which is dominant at low speeds?
- How would the motion differ on a synthetic surface versus natural grass?
- If the motion were truly uniform, what would the position-time and speed-time graphs look like?
- How does the mass of the ball affect the deceleration? Would a heavier ball decelerate more slowly?
- What is chronophotography, and how did it contribute to the development of cinema?

Going further

- Compare the deceleration of a football on different surfaces (grass, concrete, indoor court) using your own videos
- Analyze the flight phase of a kicked ball (airborne) and compare the trajectory with a parabola
- Study the speed of a ball during a penalty kick and calculate the time a goalkeeper has to react
- Compare the deceleration of different types of balls (football, tennis ball, basketball) rolling on the same surface
- Investigate whether the initial kick speed affects the deceleration rate