Speed of a skier on video

FizziQ activity · Middle school · 35 min

Scan to open in FizziQ

Point by point on a downhill video, students read horizontal and vertical velocity, then combine them with Pythagoras. FizziQ kinematics module, on smartphone.

Learning objectives

- Analyze a downhill skiing video using FizziQ kinematic tracking to determine the skier's speed
- Decompose velocity into horizontal and vertical components from the video analysis
- Reconstruct the true speed using the Pythagorean theorem: $V = \sqrt{(Vx^2 + Vy^2)}$
- Compare the calculated speed with the broadcast speed value
- Understand the limitations of 2D video analysis for 3D motion

Instruments and sensors

Video (kinematics) analysis module · Camera

Materials

- Smartphone or tablet capable of video analysis (FizziQ Kinematics module)
- Olympic Games 'Downhill' skiing video accessible via FizziQ resource library
- 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 'Downhill' skiing video from the FizziQ resource library.
2. Identify a reference scale in the video. Gate spacing, the skier's height, or course markings can be used.
3. Set the scale and define the coordinate system with x horizontal and y vertical.
4. Track the skier's position frame by frame through a section of the course where the speed appears approximately constant.
5. Collect at least 10-15 data points over 1-2 seconds of the run.
6. From the position data, calculate the horizontal velocity Vx (change in x per unit time) and the vertical velocity Vy (change in y per unit time).
7. Plot both Vx and Vy versus time. Note whether they are approximately constant or changing.
8. Calculate the total speed at each time step: $V = \sqrt{(Vx^2 + Vy^2)}$.
9. Convert V from m/s to km/h (multiply by 3.6) and compare with the speed displayed in the broadcast.
10. Discuss why the video-derived speed may differ from the broadcast speed. Consider the angle of the camera and perspective effects.
11. Analyze a section where the skier is accelerating or braking and observe how Vx and Vy change differently.
12. Create a summary table with time, Vx, Vy, V_total, and V_broadcast for each analyzed section.

Expected results

Olympic downhill speeds typically range from 80-140 km/h (22-39 m/s). The video analysis may underestimate the true speed by 10-30% due to perspective effects: the camera view does not capture the component of velocity perpendicular to the image plane (toward or away from the camera). In sections where the skier moves

parallel to the camera, the 2D analysis gives a better estimate. The horizontal component Vx dominates on gentle slopes, while Vy becomes significant on steep sections. Students should observe that the total speed V is always greater than either individual component, illustrating the Pythagorean relationship. Measurement precision is typically ±2-5 m/s due to pointing accuracy and frame rate limitations.

Questions

- Why is the total speed always greater than either the horizontal or vertical component alone?
- When is the 2D video analysis most accurate? When is it least accurate?
- What information is lost when a 3D motion is captured by a single camera?
- How could you improve the speed estimate using two cameras at different angles?
- Why does the skier's speed vary during the descent? What forces are at play?
- How do official timing systems measure the skier's speed during competition?

Going further

- Compare the speed profile of a downhill racer with that of a slalom skier from a different video
- Analyze a section with a turn and observe how the horizontal and vertical velocity components change
- Calculate the acceleration during different phases and relate it to the slope angle
- Investigate the effect of the interframe interval on the precision of the velocity measurement
- Use the kinematic data to estimate the forces on the skier (gravity, friction, air resistance)