Center of gravity of a diver

FizziQ activity · Middle and high school · 40 min

Scan to open in FizziQ

Students locate a diver's center of gravity frame by frame with FizziQ's Kinematics module on a smartphone and show it traces a parabola, from middle school up.

Learning objectives

- Identify and track the center of gravity of an articulated body (diver) during a complex movement
- Verify that the center of gravity follows a parabolic trajectory consistent with projectile motion
- Apply quadratic curve fitting to the trajectory data and extract physical parameters
- Understand the difference between the motion of the center of gravity and the motion of individual body parts
- Develop skills in video-based kinematic analysis and scale calibration

Instruments and sensors

Video (kinematics) analysis module · Camera

Materials

- Smartphone or tablet with the FizziQ application
- "Diving" video from the FizziQ resource library
- Note: the protocol remains adaptable to any comparable video analysis tool.

Protocol

1. Open FizziQ and navigate to the Kinematics module. Load the 'Diving' video from the FizziQ resource library.
2. Identify a reference scale in the video. The height of the diving platform (typically 10 m, 5 m, or 3 m) or the height of the diver can be used. Set the scale in FizziQ.
3. Define the origin of the coordinate system at a convenient fixed point (e.g., the edge of the diving board or a corner of the frame).
4. Before starting the tracking, observe the video carefully. Note how the diver's body changes shape during the jump: the center of gravity shifts relative to the torso as limbs move.
5. For each frame, estimate the position of the center of gravity. For a standing position, it is roughly at the navel. When tucked, it shifts toward the center of the curl and may even lie outside the body.
6. Begin frame-by-frame pointing by clicking on the estimated center of gravity position in each successive frame. Track from the moment the diver leaves the board until just before entering the water.
7. Aim for at least 15-20 data points across the full trajectory.
8. After completing the tracking, view the y vs. x position graph in the FizziQ notebook. The trajectory should resemble a smooth, downward-opening parabola.
9. Use the FizziQ curve fitting tool to fit a quadratic function $y = ax^2 + bx + c$ to the data.
10. From the coefficient a, estimate the acceleration of gravity: $g = -2a \times v_{0x}^2$, where v_{0x} is the initial horizontal velocity.
11. Compare the smoothness of the center-of-gravity trajectory with the trajectory of a single body part (e.g., the feet or hands), which will show oscillations due to rotation.
12. Discuss the precision of your pointing and the sources of uncertainty in estimating the center of gravity position.

Expected results

The center of gravity trajectory should form a smooth parabola with minimal scatter, even though the diver's body is rotating and changing shape. The quadratic fit should yield a coefficient of determination R^2 above 0.98 for careful tracking. The extracted value of g should be within 10-15% of 9.81 m/s², with discrepancies mainly due to the difficulty of precisely locating the center of gravity in each frame. By contrast, tracking a single body part (head, feet, or hands) will produce a trajectory with clear oscillations superimposed on the parabola, reflecting the rotational motion around the center of gravity. The horizontal velocity of the center of gravity should remain approximately constant throughout the flight, typically 1-3 m/s depending on the dive. Students may find that during tucked positions, the center of gravity can appear to lie outside the diver's body.

Questions

- Why does the center of gravity follow a smooth parabola while the diver's limbs follow much more complex paths?
- Can the center of gravity of a body lie outside the physical body? Give an example.
- How does the diver control the speed of rotation without any external force acting on them?
- Why is the Fosbury Flop technique in high jump advantageous from the perspective of center of gravity?
- What factors make it difficult to accurately locate the center of gravity in a video frame?
- How would air resistance affect the trajectory of the center of gravity during a dive?

Going further

- Compare the center of gravity trajectory for different types of dives (tuck, pike, straight) to see how body configuration affects the ease of tracking
- Track a single limb (e.g., the feet) alongside the center of gravity and plot both trajectories on the same graph to visualize the rotational component
- Use the analysis to estimate the diver's rotational speed (in revolutions per second) during a tucked somersault
- Analyze a gymnastics video (floor exercise or vault) and compare the center of gravity trajectory with that of the diver
- Investigate how changing the moment of inertia (tuck vs. layout) affects rotational speed while the center of gravity follows the same parabola