G-forces on a roller coaster

FizziQ activity · High school · 45 min

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A smartphone zipped in a pocket logs G-forces, rotation and pressure during the ride. Back in class, FizziQ data gives the altitude profile and weightless phases.

Learning objectives

- Record and analyze multi-sensor data during a complex motion
- Identify G-forces and relate bodily sensations to physical quantities
- Reconstruct an altitude profile from barometric data
- Calculate centripetal acceleration and estimate the radius of curvature
- Apply energy conservation to estimate speed at different points

Instruments and sensors

Absolute acceleration · Angular velocity · Altimeter · Accelerometer · Gyroscope · Barometer

Materials

- Smartphone or tablet with FizziQ
- A zipped pocket or armband to secure the phone
- Access to a roller coaster or amusement park ride
- Note: the protocol remains adaptable to any comparable multi-sensor data acquisition tool.

Protocol

1. Before the outing, configure FizziQ to record simultaneously: G-forces (accelerometer), angular velocity (gyroscope), and atmospheric pressure (barometer).
2. Secure your smartphone in a zipped pocket or tight armband. The phone must absolutely not fall! Verify it is firmly held.
3. Start the recording just before the ride begins.
4. Enjoy the ride! The recording runs automatically.
5. Stop the recording as soon as the ride ends.
6. Back in class, open the data and identify the different phases of the ride on the G-force graph.
7. Find the moments when the G-force exceeds 1g (bottom of loops, sharp turns) and when it drops below 1g (tops of hills, drops).
8. Look for instants where the G-force is close to 0g: these are moments of weightlessness, at the top of hills taken at high speed.
9. Use the barometer data to reconstruct the altitude profile of the ride. Compare it with a photo or diagram of the track.
10. For each loop or turn, calculate the centripetal acceleration and estimate the radius of curvature: $R = v^2/a$, where v is estimated from energy conservation.

Expected results

G-forces typically range from 0g to 3g on a standard roller coaster (up to 4-5g on extreme rides). Weightlessness moments (airtime, 0g) correspond to the tops of hills taken at high speed. The barometer shows pressure variations of 1-3 hPa corresponding to altitude changes of 10-25 m. The altitude profile reconstructed from the barometer matches the visual shape of the track.

Questions

- Why do you feel heavier at the bottom of a valley and lighter at the top of a hill?
- What is the minimum speed to pass the top of a vertical loop without falling?
- Why is the first drop always the tallest on a roller coaster?
- How can you estimate the radius of curvature of a loop from the G-force data?
- Why do clothoid-shaped loops produce less extreme G-forces than circular loops?
- At what point during the ride is the kinetic energy maximum?

Going further

- Compare data from different rides: Ferris wheel, spinning chairs, drop tower
- Estimate the power dissipated by friction over the course of the ride
- Calculate the speed at the bottom of the first drop and compare with the theoretical value from energy conservation
- Study the angular velocity data to identify inversions and corkscrews
- Compare two different roller coasters and discuss which is more 'extreme' based on the data