Uniform rectilinear motion

FizziQ activity · Middle school · 25 min

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Can you walk at constant velocity? Accelerometer and GPS recordings in the FizziQ smartphone app reveal deviations from uniform rectilinear motion. Middle school.

Learning objectives

- Attempt to walk at constant velocity in a straight line and record sensor data
- Use the accelerometer to detect deviations from zero acceleration (the URM condition)
- Use GPS position data to evaluate the straightness and constancy of the motion
- Understand the concept of a Galilean reference frame and Newton's first law
- Identify the forces that prevent perfect URM in everyday motion

Instruments and sensors

Linear acceleration · GPS speed and position tracking · Accelerometer · GPS

Materials

- Smartphone or tablet running the FizziQ app
- A clear outdoor space for walking in a straight line (at least 50 meters, e.g. a running track, corridor, or sidewalk)
- Note: the protocol remains adaptable to any comparable motion/data acquisition tool.

Protocol

1. Find a straight, flat, open space at least 50 meters long (a running track, corridor, or sidewalk).
2. Open FizziQ and select the Linear Acceleration X sensor (forward-backward axis) and, if available, add GPS Speed in Duo mode.
3. Start recording and stand still for 5 seconds to establish a zero-acceleration baseline.
4. Begin walking in a straight line at the most constant speed you can maintain. Walk for at least 30 seconds or 50 meters.
5. Stop walking and stand still for another 5 seconds.
6. Stop recording and examine the acceleration graph. During perfect URM, it should show zero acceleration throughout the walking phase.
7. Observe the reality: the graph will show oscillations from each step and possible trends from speed changes.
8. If GPS data is available, examine the speed versus time graph. How constant was your walking speed?
9. Calculate the average acceleration during the walking phase. For good URM, this should be very close to zero.
10. Calculate the standard deviation of the acceleration during walking. This quantifies how far from ideal URM you achieved.
11. Try again, this time trying to walk more smoothly. Can you reduce the acceleration fluctuations?
12. Discuss: what forces prevent you from achieving perfect URM? What would a truly inertial reference frame look like?

Expected results

The acceleration graph during walking will show periodic oscillations of approximately ±1-3 m/s² at the step frequency (about 1.5-2 Hz), superimposed on a near-zero average. The GPS speed will show fluctuations of ±0.2-0.5 m/s around a mean walking speed of typically 1.2-1.5 m/s. The average acceleration over the entire walking phase should be close to zero (typically ±0.1 m/s²), confirming that the overall motion approximates URM even though individual steps deviate. Students should observe that the standing phases show lower acceleration noise than the walking phase, and that smooth, deliberate walking produces smaller fluctuations than hurried walking.

Questions

- What does Newton's first law predict about an object in uniform rectilinear motion?
- Why is it impossible to achieve perfect URM while walking?
- What forces act on your body during walking? Do they cancel out on average?
- What is a Galilean reference frame, and how does it relate to URM?
- How would URM differ in outer space, where friction and gravity are absent?
- Why do the acceleration oscillations during walking not average to zero over a single step?

Going further

- Compare walking, running, and cycling in terms of how closely they approximate URM
- Record data on a moving train or bus and investigate whether the cabin approximates a Galilean frame
- Use the XY graph mode to plot acceleration along two axes simultaneously and evaluate straightness
- Investigate whether a toy car on a flat surface achieves better URM than human walking
- Compare the acceleration patterns at different walking speeds and determine the optimal speed for URM